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ROYAL COMMISSION ON SEWAGE DISPOSAL.

EIGHTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(Including any Liquid from any Factory or Manufacturing Process)

MAY PROPERLY BE ADOPTED.

STANDARDS AND TESTS FOR SEWAGE AND SEWAGE EFFLUENTS DISCHARGING INTO RIVERS AND STREAMS.

VOL. I.—REPORT.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
To be purchased, either directly or through any Bookseller, from
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PRINTED BY
WYMAN AND SONS, Limited, Fetter Lane, E.C.
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[Cd. 6464.] *Price 3d.*

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VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath; Our Trusty and Well-beloved Sir Richard Thorne Thorne, Knight Commander of Our Most Honourable Order of the Bath, Medical Officer of the Local Government Board; Our Trusty and Well-beloved Constantine Phipps Carey, Esquire, Lieutenant-Colonel and Honorary Major-General on the Retired List of Our Army; Our Trusty and Well-beloved Charles Philip Cotton, Esquire; Our Trusty and Well-beloved Michael Foster, Esquire, Master of Arts, Professor of Physiology in Our University of Cambridge; Our Trusty and Well-beloved Thomas Walter Harding, Esquire, Retired Lieutenant-Colonel of Our Auxiliary Forces, with Honorary Rank of Colonel; Our Trusty and Well-beloved Thomas William Killick, Esquire; Our Trusty and Well-beloved William Ramsay, Esquire, Professor of Chemistry, University College, London; and Our Trusty and Well-beloved James Burn Russell, Esquire, Doctor of Medicine, Master of Surgery: Greeting!

Whereas We have deemed it expedient that a Commission should forthwith issue to inquire and report:

1. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory, or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities; and

(2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage;

Now know ye, that We, reposing great trust and confidence in your knowledge and ability, have authorised and appointed, and do by these Presents authorise and appoint, you, the said Walter Stafford, Earl of Iddesleigh, Sir Richard Thorne Thorne, Constantine Phipps Carey, Charles Philip Cotton, Michael Foster, Thomas Walter Harding, Thomas William Killick, William Ramsay, and James Burn Russell to be Our Commissioners for the purposes of the said Inquiry.

And, for the better effecting the purposes of this, Our Commission, We do by these Presents give and grant unto you, or any three or more of you, full power to call before you such persons as you shall judge likely to afford you any information upon the subject of this Our Commission; and also to call for, have access to, and examine all such books, documents, registers, and records as may afford you the fullest information on the subject, and to inquire of and concerning the premises by all other lawful ways and means whatsoever.

And We do by these Presents authorise and empower you, or any three or more of you, to visit and personally inspect such places as you may deem it expedient so to inspect for the more effectual carrying out of the purposes aforesaid.

And We do further by these Presents will and ordain that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, and of every matter and thing therein contained, although the same be not continued from time to time by adjournment.

And We do further ordain that you, or any three or more of you, have liberty to report your proceedings under this Our Commission from time to time, if you shall judge it expedient so to do.

And Our further Will and Pleasure is that you do, with as little delay as possible, report to Us, under your hands and seals, or under the hands and seals of any three or more of you, your opinion upon the matters herein submitted for your consideration.

And for the purpose of aiding you in such matters, We hereby appoint Our Trusty and Well-beloved Frederick James Willis, Esquire, to be Secretary to this Our Commission.

Given at our Court at St. James's, the Seventh day
of May, One thousand eight hundred and ninety-eight,
in the Sixty-first Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. Ridley.

William Henry Power, Esq., F.R.S.,
To be a Member of the Royal Commission on Sewage Disposal.

VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Well-beloved William Henry Power, Esquire, Fellow of the Royal Society, Medical Officer of the Local Government Board: Greeting!

Whereas We did, by Warrant under Our Royal Sign Manual, bearing date the Seventh day of May, One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved cousin Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, or any three or more of them, to inquire into the treatment and disposal of sewage.

And whereas One of the Commissioners so appointed, namely, Sir Richard Thorne Thorne, has since deceased.

Now know ye, that We, reposing great confidence in you, do, by these Presents, appoint you, the said William Henry Power, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Sir Richard Thorne Thorne, deceased, in addition to, and together with, the other Commissioners whom we have already appointed.

Given at our Court at Saint James's, the Seventh
day of February, One thousand nine hundred, in the
Sixty-third Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. Ridley.

Whitehall, March 18th, 1901.

THE KING has been pleased to issue a Commission, under His Majesty's Royal Sign Manual, to the following effect :—

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland King, Defender of the Faith, to all to whom these Presents shall come, Greeting !

Whereas it pleased Her late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified :

And whereas, in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission ;
The Horse Breeding Commission ;
The Local Taxation Commission ;
The Port of London Commission ;
The Salmon Fisheries Commission ; and
The Sewage Disposal Commission ;

the Commissioners appointed by Her late Majesty, or such of them as were then acting as Commissioners, were, at the late demise of the Crown, still engaged upon the business entrusted to them :

And whereas, We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown :

Now know ye, that We, reposing great trust and confidence in the zeal, discretion, and ability of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissions do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration ; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the fourth
day of March, One thousand nine hundred and one,
in the First Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

THOMAS JOSEPH STAFFORD, F.R.C.S.I.
To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith. To Our Trusty and Well-beloved Thomas Joseph Stafford, Esquire, Fellow of the Royal College of Surgeons of Ireland, Medical Commissioner of the Local Government Board for Ireland : Greeting !

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, to be Commissioners to inquire into the treatment and disposal of Sewage.

And whereas, one of the Commissioners so appointed, namely, Our Trusty and Well-beloved Charles Philip Cotton, Esquire, hath humbly tendered unto Us his resignation of his appointment as one of the said Commissioners :

Now know ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Thomas Joseph Stafford, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Charles Philip Cotton, resigned, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of May, One thousand nine hundred and two, in the Second Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

REGINALD ARTHUR TATTON, ESQUIRE,
To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R. & I.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith, To Our Trusty and Well-beloved Reginald Arthur Tatton, Esquire, Greeting !

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May, One thousand eight hundred and ninety-eight, appoint Commissioners to inquire into the treatment and disposal of Sewage.

And whereas, a vacancy has been caused in the body of the Commissioners appointed as aforesaid by the death of Major-General Constantine Phipps Carey, C.B.

Now know ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Reginald Arthur Tatton, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Constantine Phipps Carey, deceased, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of January, One thousand nine hundred and seven, in the Sixth Year of Our Reign.

By His Majesty's Command,
(Signed) H. J. GLADSTONE.

Whitehall, May 30th, 1910.

The King has been pleased to issue a Warrant under His Majesty's Royal Sign Manual to the following effect:—

GEORGE R. & I.

George the Fifth, by the Grace of God, of the United Kingdom of Great Britain and Ireland, and of the British Dominions beyond the Seas King, Defender of the Faith, to all to whom these Presents shall come. Greeting!

Whereas it pleased His late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified:

And whereas, in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission;
The Horse Breeding Commission;
The Sewage Disposal Commission;
The Poor Laws Commission;
The Tuberculosis Commission;
The Canal Communication Commission:
The Mines Commission;
The Welsh Church Commission;
The Coast Erosion and Afforestation Commission;
The Vivisection Commission;
The Land Transfer Acts Commission;
The Ancient Monuments (Wales and Monmouthshire) Commission;
The Ancient Monuments (England) Commission;
The Trade Relations between Canada and the West Indies Commission;
The Selection of Justices of the Peace Commission;
The Divorce and Matrimonial Causes Commission;
The University Education in London Commission; and
The Brussels, Rome and Turin Exhibitions Commission;

the Commissioners appointed by His late Majesty, or such of them as were then acting as Commissioners, were at the late demise of the Crown, still engaged upon the business entrusted to them:

And whereas, We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown:

Now know ye, that We, reposing great trust and confidence in the zeal, discretion, and ability, of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissioners do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown and, before the issue of these Presents shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the twenty-sixth day of May, One thousand nine hundred and ten, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) R. B. Haldane.

FREDERICK JAMES WILLIS, ESQ.,
To be a Member of the Royal Commission on Sewage Disposal.

GEORGE R. & I.

George the Fifth, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith: To Our Trusty and Well-beloved Frederick James Willis, Esquire, Barrister-at-law, one of the Assistant Secretaries to the Local Government Board. Greeting!

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh day of May, One thousand eight hundred and ninety eight, appoint Commissioners to inquire into the treatment and disposal of Sewage:

Now know ye, that We, reposing great confidence in you do by these Presents appoint you the said Frederick James Willis, sometime Secretary to the said Royal Commission, to be an additional Commissioner for the purposes aforesaid.

Given at Our Court at Saint James's the Twentieth day of July, One thousand nine hundred and ten, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) W. S. CHURCHILL.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

EIGHTH REPORT.

To The King's Most Excellent Majesty:

May it Please Your Majesty:

We, your Commissioners, appointed to inquire into the methods of disposing of sewage and trade effluents, humbly submit a further Report.

Preliminary.

1. In this Report we propose to deal with the question of the standards to be applied to sewage and sewage effluents discharging into rivers and streams, and the tests which, in our opinion, should be used in determining those standards.

In our next and final Report we shall deal with methods of disposal not involving water carriage and with standards in regard to trade effluents.

2. In paragraphs 311 and 312 of our Fifth Report we stated as follows:—

> "311. The evidence adduced before us and the results of our own investigations show that the extent to which the purification of a sewage need be carried in order that none of the other injuries mentioned in paragraph 303 shall be done to the river into which it is discharged varies with the particular circumstances of the town and river concerned.
>
> "The statute law, however, recognises no graduated standards of purity for sewage effluents.
>
> "Under the Rivers Pollution Prevention Act, 1876, in the case of sewage entering non-tidal waters, the duty is imposed on the local authority of adopting the best practical and available means to render the sewage harmless before it enters the river, and no local circumstances may be taken into account. The effluent by itself is alone to be considered."
>
> "312. We fully realise that from the point of view of administration it is simpler to regard the effluent alone, and also that it has not been usual for County Councils, Rivers Boards, or others, to press the provisions of the Act of 1876 unduly. Our terms of reference require us, however, to have regard to the '*economical* and efficient discharge' of the duties of local authorities, and in view of the importance of not requiring a local authority to incur any further expenditure on sewage disposal than the circumstances of its area require, we feel strongly that the law should be altered so as to allow local circumstances to be taken into account."

3. Since the issue of that Report we have devoted much time to the object of ascertaining the extent to which it may be practicable to take local circumstances into account and the machinery by which this may be done.

We have through our officers kept under observation a considerable number of rivers and streams of different types with a view to tracing the effects of discharging various sewage liquids of known composition and volume into streams of known quality, volume and velocity; and some of us have personally inspected a number of these streams.

The data thus obtained indicate clearly that the volume and other conditions of a stream are factors which in ordinary circumstances go far to determine whether obvious nuisance would or would not be caused by the discharge of sewage liquids into that stream, and we reiterate our recommendation that the law should be altered so that local authorities should not be required to purify their sewage more highly than is necessary to obviate the risk of actual nuisance arising from its discharge.

The Connexion between the Physical and the Chemical Conditions of Streams Receiving Sewage Liquids.

4. In order to facilitate the practical working of the above recommendation it is clearly desirable that the authorities concerned should be in a position to know whether the discharge of a given sewage liquid into a given stream will or will not cause signs of pollution to manifest themselves. We have, therefore, endeavoured to discover whether there is correspondence between the observed condition of a contaminated stream and the analysis of its waters sufficient to enable us to deduce from the chemical figures what will be the physical condition of the stream in regard to nuisance; *e.g.*, in regard to smell, over-development of grey algal growths, accumulation of putrefying sewage solids and detriment to fish life.

5. With this object in view our officers have applied various chemical tests to samples of different river waters drawn at various points. The condition of the stream at each point has been noted, and its volume, velocity, depth and degree of aeration have been ascertained. From these data it has been possible to trace a general correspondence between the observed physical conditions of the stream and the analytical figures obtained in the laboratory.

The degree of correspondence as might be expected has been found to vary considerably in different streams and also in the same stream under different conditions, and we have, therefore, endeavoured to test the reliability of our chemical indices of pollution in a practical manner. Having ascertained from certain local authorities the volume of their effluents and their chemical composition, as judged by the tests which we have adopted, and the volume and velocity of the streams into which those effluents respectively discharge, our officers attempted to deduce from these data what signs of pollution, if any, should be found in the streams. Independent visits to the localities were then made in order to compare the conditions forecasted with those actually observed on inspection.

6. Our officers also kept under continuous observation sewage liquors and effluents of different strengths flowing in some cases by themselves, and in others diluted with water in artificial channels, and compared the observed condition of the channels at different seasons of the year with the corresponding figures of chemical analysis.

These experiments were carried out at Chorley, Caterham, Dorking and Kingston. We regard them as an important supplement to the stream observations as they render it possible to observe the behaviour of the liquors (whether crude or mixed with different proportions of tap-water) apart from the varying and disturbing factors which are present in every case of sewage liquors discharging into streams, and thus enable us to trace more directly the chemical changes occurring in the liquors under observation.

Our data have been further supplemented by a considerable body of information relating to the chemical quality of sewage liquids, with which we have been furnished by the courtesy of a number of local authorities.

Tests for Sewage Liquids in Relation to Streams.

7. The materials which we have thus collected form a wide basis for estimating the comparative value of different chemical tests in measuring the ability to produce nuisance possessed by a sewage liquid which yields certain data on chemical analysis.

Various tests or series of tests are now employed for the purposes of working standards by existing Rivers Boards. We have, after abundant experience of a great variety of tests, confined our attention mainly to three, viz. :—

(1) The amount of ammoniacal nitrogen present;
(2) The amount of oxygen absorbed from permanganate in 4 hours; and
(3) The amount of dissolved oxygen taken up in 5 days.

The relative values of these and other tests are discussed at length in the Appendix; and it will be sufficient here to summarise the conclusions at which we have arrived.

8. It may be taken that the most delicate chemical index of recent sewage pollution of a river water is to be found in the figure for ammoniacal nitrogen. This determination is one of great accuracy and may be relied on to show very small differences in degree of existing pollution. But it is not equally reliable in indicating the *character* of the pollution, as shown by the effect which the discharge of a given sewage liquor is likely to have upon the stream, and we have, therefore, endeavoured to find a test which should be capable of giving such an indication.

The chemical changes which occur in polluted water have been described by Dr. Adeney, whose general conclusions are quoted on pp. 11–14 of our Fifth Report. He states that :—

> "The most important change which occurs in an unpolluted water, when it is mixed with sewage or other water-borne refuse matter, is the more or less rapid absorption of its dissolved oxygen."

Our investigations show that the nuisance-producing power of a normal sewage or effluent (apart from questions of temperature) is broadly proportional to its power of deoxygenating the water of a stream, and that tests which are based upon the rate and degree of absorption of oxygen are the most trustworthy tests for determining whether nuisance is or is not likely to be caused in a stream by the discharge of such liquids.

9. We now come to consider the relative merits of the two tests referred to in paragraph 7 which take into account the absorption of oxygen.

The test for oxygen absorbed in 4 hours from permanganate has the advantage of being more speedily determined and somewhat easier to work than the test for dissolved oxygen taken up in 5 days, which is, in essence, a bacteriological test. But we think that these advantages are outweighed by the following considerations :—

(1) We have found, in practice, that the 5 days' test reflects more accurately than the permanganate test the observed conditions of the streams.

(2) The 5 days' test represents more naturally the actual process by which the more readily oxidizable constituents of the polluting matter absorb the oxygen dissolved in the river water. Permanganate, on the other hand, is a vigorous oxidizing agent which may oxidize substances contained in the polluting matters which would not take up dissolved oxygen under natural conditions, at all events not at a rate which would de-oxygenate a stream.

(3) Laboratory experiments have shown that it is the more delicate test of the two, *i.e.*, it shows smaller differences in quality of water. For example, the permanganate test may give approximately the same figure for a water polluted with tank liquor and for a water polluted with filter effluent, while the 5 days' dissolved oxygen test applied to the same liquids would give a higher figure for the water polluted with the tank liquor, thus indicating differences in kind as well as in degree of pollution.

THE DISSOLVED OXYGEN ABSORPTION TEST AS THE BASIS OF A STANDARD.

10. For the reasons indicated above we think that the dissolved oxygen absorption test provides the most trustworthy chemical index of the actual state of a stream, and should be adopted for purposes of a standard.

Objection has been raised to this test on the grounds that it is difficult to carry out and gives discordant results. This objection is not well founded. A considerable number of chemists at different sewage works have made numerous analyses for us with this test, and we are satisfied that with a little practice any well-trained chemist can use the test with ease and obtain accurate results. It now becomes necessary to consider in what way this test should be employed if adopted as the basis of a standard or range of standards.

Our officers have submitted to this test a large number of samples drawn from various streams : (*a*) at points where signs of sewage pollution were observed ; and (*b*) where there were no signs of pollution. By comparing the results of analyses of the two sets of samples it was hoped to arrive at a figure for dissolved oxygen absorption in 5 days which should represent a limit not to be exceeded without signs of pollution being likely to manifest themselves.

11. In view of the variations, both seasonal and local, in the conditions common to streams receiving sewage liquids, it is obvious that such a figure can only be an approximate one. But the data thus obtained, supplemented by the results of the channel experiments, justify us in concluding that if 100,000 cubic centimetres of river water do not normally take up more than 0·4 gram of dissolved oxygen in 5 days the river will ordinarily be free from signs of pollution, and that if a river water normally gives a higher figure than this it will almost certainly show signs of pollution except perhaps in very cold weather. (For the sake of brevity we shall, hereafter, refer to "grams per 100,000 cubic centimetres" as "parts per 100,000.")

This figure (0.4) we term the "limiting figure," and in our opinion it should be the foundation upon which any scheme of standards should be constructed.

Temperature, however, is an important factor, and if the 5 days' test be carried out at the different temperatures which prevail at different seasons in our streams, the results will be found to vary to a marked extent. Our experiments have been carried out at the temperature of 65° F. Assuming 0·4 to be the true "limiting figure" at this temperature, during the colder months of the year a river could withstand, without nuisance, much worse pollution. To preserve a wide margin of safety we have adopted the temperature of 65° F. and, for the same reason, the dry-weather flow of the river.

ON METHODS OF APPLYING A STANDARD.

12. A chemical standard may be applied in one of two ways—either to the contaminating discharge by itself or to the stream which has received the discharge. Since our main objective is primarily the improvement of rivers, and only secondarily the improvement of effluents, it would seem logical that standards should be applied not to sewage liquors or effluents alone but to such discharges under ordinary conditions, *i.e.*, when mixed with the river water.

On this principle it would be sufficient to apply the dissolved oxygen test to the river water at a point where it has received and mingled with the polluting discharge. The standard would be fixed at 0·4, and if the mixture should yield a figure exceeding the standard, then the sewage liquor or effluent would have to be improved.

13. The amount of dissolved oxygen taken up in 5 days by a mixture of river water and sewage liquor depends: (*a*) on the amount taken up by the sewage liquor; (*b*) on the amount taken up by the river water; and (*c*) on the proportion in which the two liquids are combined. A mixture complying with the above standard may thus be expressed in the form of an equation as follows:—

$$\frac{x + yz}{z + 1} = 0{\cdot}4$$

when x = parts of dissolved oxygen taken up per 100,000 by effluent.
y = parts of dissolved oxygen taken up per 100,000 by river water above outfall.
z = dilution (proportion of river water to effluent).

By applying this formula to the case of any discharge of sewage liquor or effluent into a stream, it would be possible to ascertain (the quality of the stream water and the dilution being known) the minimum degree of purification which would be sufficient to obviate risk of nuisance.

Thus, if an effluent is discharged into 10 times its volume of water which itself takes up 0·1 parts of dissolved oxygen in 5 days, the formula gives:—

$$\frac{x + (0{\cdot}1 \times 10)}{10 + 1} = 0{\cdot}4$$
$$x + 1 = 4{\cdot}4$$
$$x = 3{\cdot}4$$

That is, the effluent in this case may be permitted to take up 3·4 parts of dissolved oxygen per 100,000 in 5 days, and that figure would be the standard for this particular discharge.

14. A system of standards framed on these lines would at first sight seem to effect by the simplest means the object which we have in view, viz., that a local authority should not be required to incur further expenditure on sewage disposal than the circumstances of the area require.

But such a system generally applied would be open to three serious objections:—

(*a*) It would be very difficult to administer.

(*b*) It would distribute the burden of purification unequally as between different authorities in the same watershed.

(*c*) It would go farther in the direction of differentiation than is necessary to ensure economy.

15. (*a*) The system would involve the difficulty of requiring, in effect, a different standard of purity for the sewage or effluent of each place, and it will be readily understood that multiplication of standards multiplies the difficulties of administering them.

(*b*) In the ordinary case of a river receiving successive pollutions at intervals along its course, the quality of the water will tend to deteriorate from source to tideway, unless the intervals should be so wide or the influx of clean tributary water so great, as to permit the river to recover naturally from the effects of one pollution before it received the next. To comply with a standard applied to the mixture of sewage liquor and river water the quality of the discharge would have, broadly speaking, to vary inversely with the quality of the river water. Thus more purification would be required of the lower of two towns because less was required of the higher. The rigid enforcement of such a standard might cause hardship to the communities lower down the stream, while those higher up were treated with needless leniency.

(*c*) Differentiation between standards of purity is of no economic advantage unless it is large enough to permit the substitution of a cheaper for a more expensive process of treatment. Hence any graduation of standards should be determined in relation to the degrees of purification attainable in practice by different systems of treatment properly supervised. To permit a low standard of purity where a higher one can be attained by efficient management of the same plant is to inflict injury on the river without securing any corresponding advantage.

We do not therefore recommend a system by which the degree of purification required for each separate discharge is determined automatically by the quality and the relative quantity of the water receiving it. Quality and quantity of river water are however highly important local conditions of which account should be taken in framing systems of standards, and the question of their relative importance in administration needs to be determined.

In our view one normal standard should be fixed which would be suitable for the majority of places, and provision should be made for fixing one or two higher or lower standards to meet cases in which a different standard could be justified.

Quality of Water as a Factor in a Graduated Scale of Standards.

16. For the reasons given above the taking into account of variation in quality of the diluting water has the effect of imposing unequal burdens upon the various local authorities who discharge their sewage or effluents into a river. A local authority is not responsible for the quality of the water which comes down to its works. But a superior authority having jurisdiction over the whole of a watershed will be largely responsible for the general quality of the waters within its area, and by the enforcement of appropriate standards will aim at reducing this inequality to a minimum.

We consider, therefore, that variations in the quality of the diluting water should not be taken into account in fixing standards.

17. In the course of our investigations we classified a number of rivers or reaches of rivers under a series of groups according to the appearance which they presented to the observer. These groups were described respectively as "very clean," "clean," "fairly clean," "doubtful" and "bad." A number of samples from each group were submitted to the 5 days' dissolved oxygen absorption test, among various other tests, and the average figure for each group was taken. These average figures were found to be as follows :— App. Pt. II. 4.

Very clean - - - -	0.1	part dissolved oxygen in 5 days.
Clean - - - -	0·2	,, ,, ,,
Fairly clean - - - -	0·3	,, ,, ,,
Doubtful - - - - -	0·5	,, ,, ,,
Bad - - - - - -	1·0	,, ,, ,,

It is obvious that a river water which itself takes up 0·4 part dissolved oxygen or more is useless, or worse than useless, if dilution is to assist in keeping the mixture at or below that level, and the last two classes of water need not be considered. As regards the remaining three groups, we do not think it would be safe to credit local authorities generally with the advantage of diluting their effluent with "very clean" water. On the other hand, it would not be fair to restrict them to the limited benefit obtained from dilution with a water which itself takes up 0·3 part of dissolved oxygen. Such a water may be assumed to be still affected by previous pollution which ought to be remedied at the point or points of origin.

We think, therefore, that the second group may be taken as fairly representing what should be regarded as the average quality of rivers under ordinary conditions, and that for the purpose of arriving at a standard or scale of standards the quality of the diluting water should be assumed to be constant and represented by the figure 0·2.

Dilution as a factor in Determining the Selection of a Standard.

18. Of the various local conditions which should be taken into account in considering the question of standards by far the most important in our view is the degree of dilution afforded by a river to a contaminating discharge. The importance of this factor is sufficiently shown by the numerous instances in which the degree of dilution is sufficient to enable practically the whole work of sewage purification to be done by natural agencies without cost or injury to the community. Assuming, as we may for the reasons just given, that the diluting water is of a reasonable purity, we shall expect to find in the degree of dilution a measure alike of the amount of purification which may safely be entrusted to the river, and of the amount of purification of the polluting liquid which should be effected prior to the liquid being discharged into the river.

19. Methods of sewage treatment may be classified according to the extent to which they carry the process of purification.

Thus we have :—

(1) Simple settlement or septic tank treatment.
(2) Settlement with the aid of chemical precipitation.

These may be described as incomplete systems.

And (3) complete systems, including biological treatment of the liquor in artificially constructed filters or on land.

These methods are here arranged in ascending order of efficiency and also, broadly speaking, in ascending order of cost. Experience can tell us the degree of purification which each process may properly be expected to attain, and on the other hand, the minimum dilution available in any particular instance can be approximately ascertained. From these data the process which would be required in each case can be determined.

A Normal Standard for Effluents.

Fifth Report, paras. 313–314

20. In our Fifth Report we indicated the view that for cases in which complete treatment is required, an effluent would generally be satisfactory if it complied with certain conditions, as to the amount of suspended solids which it contained, and the amount of dissolved oxygen which it would take up. The importance of limiting the quantity of suspended solids in an effluent was insisted on in that Report, where it was shewn that a standard of 3 parts of suspended matter per 100,000 had, in fact, been commonly attained by effluents from a number of places.

322 We repeat our recommendation that a standard effluent should not contain more than that proportion of suspended solids. This test should, we think, be the primary test. Any sample which fails to pass this test should be rejected forthwith. Samples which satisfy this test must also be considered with reference to the further test of the amount of dissolved oxygen which they will absorb in 5 days.

21. As regards the dissolved oxygen absorption test we stated that an effluent would generally be satisfactory if after being filtered through filter paper it did not absorb more than 1·5 parts by weight per 100,000 of dissolved or atmospheric oxygen in 5 days. Our subsequent investigations, however, show that the practical difficulties in the way of removing suspended solids in a uniform manner, either by filter paper or otherwise, are serious.

After allowing due weight to the suggestion respecting the removal of solids which we provisionally put forward and to the plea that the solids will already have been subjected to the test for suspended matter and should not in equity be reckoned again, we think upon a balance of considerations that the dissolved oxygen absorption test should be applied to the effluent as discharged, *i.e.* with its suspended solids.

22. We recommend that the normal figure for the dissolved oxygen absorption test should be fixed at 2·0 parts per 100,000. In considering this figure we have, as in the case of the figure (3·0) for suspended solids, taken into account the results which have in practice been attained by various methods of treatment; and we rely not only on analyses made by our own officers but also on analytical and other data furnished at our request by a number of local authorities, when we assert the practicability of compliance with the standard which we propose, although when allowance is made for the oxygen taken up by the solids it is slightly more stringent than that previously suggested by us.

An effluent which takes up 2·0 parts of dissolved oxgyen in 5 days will need some dilution if nuisance is not to be caused. The minimum degree of dilution required for safety can be ascertained by applying the formula on the lines already indicated, thus :—

$$\frac{2 + (0{\cdot}2 \times z)}{z + 1} = 0{\cdot}4$$

$$z = 8$$

We think it may safely be assumed that the great majority of effluents are diluted by more than 8 times their volume of river water. This statement is certainly true of the cases which have come under our review—many of which were specially selected on account of the small dilution obtained by them.

We recommend, therefore, that in the cases in which a complete system is called for, the effluent should not contain more than 3 parts of suspended matter per 100,000 and that, including its suspended matters,* it should not take up more than 2 parts of dissolved oxygen per 100,000 in 5 days at 65° F. (18·3° C.).

This standard should be regarded as the normal standard for effluents.

23. There are some exceptional cases in which owing to the relatively small volume of the river water a more stringent standard than the normal will be called for if nuisance is to be avoided, and on the other hand, certain conditions of dilution warrant relaxation of the normal standard.

But whatever be the standard adopted we must here recall the statement made in our Fifth Report that under no circumstances must compliance with that standard be held to justify the use for drinking purposes of streams receiving those effluents without subsequent treatment by the waterworks authority.

Specially Stringent Standards.

24. The cases in which a specially stringent standard will be required are likely, as we have said, to prove exceptional, and on this ground we do not attempt a precise definition of such a standard. We think that it will be necessary to consider each case on its merits, and that special consideration of local needs and local possibilities can alone be trusted to determine what will protect sufficiently the amenities of the river without incurring needless expense.

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* The methods which we suggest should be adopted in carrying out both tests will be found fully described in the Appendix.

In extreme cases, where not only the relative volume of the stream is very small, but its actual quality is very poor, the most exacting standard which could be attained might be insufficient to prevent the occurrence of offensive conditions. Even in this case we consider that regard should not be had to the quality of the water, but only to the dilution, reliance being placed on the uniform enforcement of the appropriate standards in the higher reaches proving effective, in so far improving the quality as to prevent nuisance arising when the stream had received the discharge in question.

RELAXATION OF NORMAL STANDARD.

25. In our opinion there are circumstances in which sewage, either partially treated or not treated at all in the accepted sense, may properly be discharged into streams or rivers. We recognise in entertaining this proposition that we must meet the argument which is advanced against any standard which falls short of the highest possible—an argument which increases in force in direct proportion to the laxity of the standard. We fully admit that the general result of a standard is a levelling down as well as a levelling up; that a standard while it rejects the worse does nothing to encourage the better; that its influence is static not dynamic, it tends to produce a balance rather than a progression. Theoretically, this argument holds true; as applied to the practical problem before us it may be discounted.

We think that a claim for a relaxed standard may be entertained under the following conditions:—

(*a*) When it can be shown that the particular river water is of such quality and volume that when mixed with a sewage or sewage liquor of known or calculated strength and volume it does not or would not take up more than 0·4 part per 100,000 of dissolved oxygen in 5 days; and

(*b*) When there is reason to suppose or when it can be shown that the river will receive no further pollution until it has recovered itself so far as not to take up in 5 days an amount of dissolved oxygen much in excess of that which it took up before receiving the first discharge.

CONDITIONS UNDER WHICH IT MAY BE PERMISSIBLE TO DISCHARGE PARTIALLY PURIFIED OR UNPURIFIED SEWAGE INTO A STREAM.

26. The main effect of what we have called incomplete systems of treatment—such as treatment in septic tanks, or by settlement with or without the aid of chemical precipitants—is the reduction of the solids suspended in the sewage. The dissolved impurities are very little affected by such treatment; in their case the main process of purification does not begin until after they have been mixed with the oxygenated water of the river. Hence it is clear that the appropriate test for these liquors as discharged is one which takes account only of the amount of suspended matter—the river itself being left to deal with the dissolved impurities.

27. If the discharge of tank liquors is not to cause nuisance, two conditions are essential, viz.:—

(*a*) Sufficient dilution with comparatively clean water (*i.e.*, water taking up considerably less than 0·4 part of dissolved oxygen in 5 days);

(*b*) Sufficient reduction of the suspended solids.

In the case of the discharge of crude sewage, where the river becomes wholly responsible for rendering harmless both the suspended and the dissolved impurities, the dilution to be afforded must obviously be very much greater, and the conditions must be such as to prevent marked accumulation of solids in any particular spots.

(*a*) *Minimum Permissible Degree of Dilution for Sewage Liquors.*

28. We have then to consider in the first place what degrees of dilution may safely be regarded as sufficient to effect such natural purification of various tank liquors and crude sewages as will prevent nuisance arising from their discharge into streams. In order to arrive at an answer to this question we have followed three lines of procedure.

(i.) On the basis of the 5 days' dissolved oxygen absorption test we have taken the average figures given by the liquor and the diluting water respectively, and calculated by means of the formula already given the number of dilutions which would be necessary to bring the resulting figure for the mixture down to our "limiting figure" of 0·4 part per 100,000.

(ii.) Taking as a basis the rate of absorption of atmospheric oxygen by water and the rate of de-oxygenation by the admixture of various sewage liquids, we have calculated the number of dilutions which would be required in order that the dissolved oxygen content of the mixtures should not fall below a certain figure.

(iii.) We have kept under observation places where partially purified or unpurified sewage is discharged into streams and noted the effects produced at different seasons, and under different conditions.

29. As regards (i.) if we know the respective amounts of dissolved oxygen taken up by the sewage liquor and by the river water into which it is discharged, we can by applying the formula referred to above, arrive at the degree of dilution which will be required if the mixture is not to yield a figure higher than the "limiting figure." In the following table (A) instances are given of this calculation as applied to typical sewage liquids discharging into waters of different qualities (as measured by the 5 days' test).

We have given in this table calculations based on three different qualities of diluting water, but for the reasons already indicated we think that for the practical purposes which we have in view the water should be assumed to take up 0·2 part of dissolved oxygen. We therefore confine our attention to column B of the table.

30. It will be seen that five types of tank liquor are instanced in the table, viz. a weak precipitation liquor, an average precipitation liquor, an average septic tank liquor, a strong precipitation liquor and a strong septic tank liquor, taking up respectively 10, 15, 20, 20 and 33 parts of dissolved oxygen in 5 days. But for the reasons already indicated we doubt whether it is necessary to distinguish between all these cases for the purpose of calculating the minimum dilution which will be needed if nuisance is to be prevented. We consider that the safe course will be to take into account the strongest liquor yielded by each of the two processes, viz., the strong precipitation liquor, and the strong septic tank liquor, and we thus arrive at 98 and 163 as the minimum permissible dilutions if those classes of liquor are to be discharged.

31. Similarly, as regards sewage, figures are given for an average sewage and a strong sewage, taking up respectively 35 and 50 parts of dissolved oxygen in 5 days. According to the Table at least 173 and 248 dilutions with clean water will be required if the discharge of these liquids is not to cause nuisance. If, as in the case of tank liquor, we base our calculation on the stronger liquid, we may say that in round numbers 250 dilutions are the minimum permissible, if crude sewage is to be discharged into a stream.

32. It must, however, be borne in mind that these minimum figures of 98, 163, and 250 dilutions for strong precipitation liquor, strong septic tank liquor and strong crude sewage only secure that the stream after receiving a discharge from a single source will not be likely to develop positive nuisance, seeing that it will not take up more than 0·4 part of dissolved oxygen in 5 days. They give no guarantee that, in the probable event of a fresh pollution occurring lower down, the water will have recovered sufficiently to prevent nuisance arising at this second point. It would thus be the aim of the responsible authority to ensure not only that the river water should take up no more than 0·4 part of dissolved oxygen immediately below the first point of pollution, but that it should take up no more than 0·2 part immediately above the second. To secure this object a considerable margin of safety should be allowed, and we suggest that the figures of 98 dilutions for precipitation liquors, 163 dilutions for tank liquors produced without the use of chemicals, and 250 for crude sewages should be raised to 150, 300 and 500 respectively, with the proviso that the condition of the river must be such as to prevent the accumulation of solids in any particular spots to an extent likely to cause nuisance.

In suggesting the figure of 150 we have considered that a smaller margin of safety is necessary in the case of sewage liquids containing the smaller amount of suspended solids.

33. As regards (ii.), our second line of investigation traces a connection between the actual oxygen content of a river water and the condition of the river as regards nuisance. Generally speaking, water which remains saturated with oxygen will not give rise to offensive conditions. Such a water contains, at ordinary temperatures, from 6 to 7 cc. of oxygen per litre. The decomposition of organic matter introduced by sewage liquor into the water has the effect of withdrawing some of this oxygen from solution. Our observations show that when the oxygen of the river is thus reduced to about 4·0 cc. per litre, the water is usually in a doubtful condition, and is on the verge of producing nuisance ; when the oxygen is reduced still lower, nuisance may be expected to arise and become increasingly apparent to the senses.

Under natural conditions, however, the river water, while yielding oxygen to the unstable organic matters which are discharged into and mixed with it, is concurrently absorbing a fresh supply of oxygen from the atmosphere (and at certain seasons from plants) at a rate which depends on various conditions, but more particularly on the depth and velocity of the stream.

TABLE A.

Type of Sewage Liquor or Effluent.	Dissolved oxygen taken up in 5 days by typical sewage liquors of various kinds.	Dilution theoretically permissible to give a mixture not taking up more than 0·4 part per 100,000 dissolved oxygen in 5 days.		
	Parts per 100,000.	A. With very clean river water taking up 0·1 part dissolved oxygen in 5 days.	B. With clean river water taking up 0·2 part dissolved oxygen in 5 days.	C. With fairly clean river water taking up 0·3 part dissolved oxygen in 5 days.
(1) A very good filter effluent - - - - - - - - -	0·5	0·33 dilution	0·5 dilution	1·0 dilution
(2) A standard effluent - - - - - - - - - - -	2·0	5·0 dilutions	8·0 dilutions	16·0 dilutions
(3) A bad effluent from filtration - - - - - - - - -	5·0	15·0 ,,	23·0 ,,	46·0 ,,
(4) A weak precipitation liquor - - - - - - - - -	10·0	32·0 ,,	48·0 ,,	96·0 ,,
(5) An average precipitation liquor - - - - - - - -	15·0	48·0 ,,	73·0 ,,	146·0 ,,
(6) An average septic tank liquor - - - - - - - - -	20·0	65·0 ,,	98·0 ,,	196·0 ,,
(7) A strong precipitation liquor - - - - - - - - -	20·0	65·0 ,,	98·0 ,,	196·0 ,,
(8) A strong septic tank liquor - - - - - - - - -	33·0	109·0 ,,	163·0 ,,	326·0 ,,
(9) An average sewage - - - - - - - - - - -	35·0	115·0 ,,	173·0 ,,	346·0 ,,
(10) A strong sewage - - - - - - - - - - -	50·0	165·0 ,,	248·0 ,,	496·0 ,,

The degree of de-oxygenation depends upon the amount of oxygen available in the water. By increasing the amount of oxygenated water with which the sewage is mixed, the loss of oxygen can be reduced to such small proportions that it is counteracted by the natural process of re-oxygenation.

34. We have not at our disposal the materials for directly ascertaining what this latter rate will be under different conditions; but we have some indirect evidence in the results obtained by Colonel W. M. Black and Professor Earle B. Phelps* from their experiments upon still water at different depths. From a table very kindly prepared for us by Professor Phelps we deduce corresponding figures for moderately rapid and very sluggish streams, based on the assumption that in the former mixing will be complete in 1 hour and in the latter in 6 hours. The following Table B. shows for liquids similar to those in Table A. the dilutions with clean water which would be required in each case to prevent de-oxygenation below 4·0 cc. This figure may be taken as corresponding with the limiting figure of 0·4 part per 100,000 given by the 5 days' dissolved oxygen test, and the quality of the diluting water is the same as that given in Column B. of Table A. The requisite dilutions indicated by the two Tables are thus directly comparable.

If we take, as before, a strong precipitation liquor and a strong septic tank liquor, it will be seen that 60 and 145 dilutions are respectively required to prevent de-oxygenation below 4·0 cc. if the stream is sluggish, and its depth 2 feet 6 inches. These figures are in reasonable agreement with the figures shown in Table A.

A strong sewage discharging into a stream of similar velocity and depth would require 185 dilutions (a figure which may be compared with the figure 248 given by the previous table).

35. It will be observed that the rates of re-oxygenation shown in Table B. vary very much according to the depth of the water, with corresponding variations in the number of dilutions. The figures are of particular interest in so far as they agree with figures arrived at by a different method. The hypothesis as to rates of mixing on which the calculations are based is founded on a large number of experiments with fluorescine in rivers and streams, but it remains a hypothesis, and the figures can only be regarded as rough approximations.

Appendix: Part II.—3. 36. As regards (iii.), the results of our riverside observations on the discharge of tank liquor and crude sewage are fully set out in the Appendix. So far as tank liquor is concerned our data on the subject are very limited, for the reason that we have had great difficulty in finding suitable instances of the discharge of tank liquor into non-tidal waters.

We found at one end of the scale a strong tank liquor discharging into 960 volumes of water, and, at the other, an effluent so poor that it might be described as a tank liquor diluted with only 10 times its own volume. In the former case, apart from the deposition of mud, the only noticeable result was a very small quantity of grey algal growth over a limited area. In the latter case, as might be expected, the stream was badly fouled.

Appendix. 37. These observations have been supplemented by the results of our channel experiments (described in the Appendix), in which tank liquors of known composition were caused to flow down artificial channels both undiluted and with certain dilutions of tap-water. In this series the crucial experiment was one in which dilution of a weak precipitation liquor with 19 volumes of clean water (0·15) was just insufficient to prevent objectionable conditions occurring in the channel. From the figures showing the strength† of this liquor and the quality of the water with which it was diluted, we arrive at a calculation of 92 dilutions as the minimum allowable for a *strong* precipitation liquor, and of 147 dilutions for a strong septic tank liquor. It will be seen that these figures show considerable agreement with those in Tables A. and B., which were calculated on different bases.

38. As regards the discharge of crude sewage, we have had under observation a larger number of instances than in the case of tank liquor. But here, too, in the majority of cases the dilution afforded by the streams was so great (ranging from 660 volumes to 1,060 volumes in dry weather) that no nuisance other than merely local fouling of the river bed was in fact caused, nor was indeed to be expected. Our observations only include one instance of a crude sewage discharging into a stream which afforded a dilution approaching what we are led to consider the minimum permissible degree for such liquor. Here the dry weather volume of the stream was to the volume of sewage in the proportion of about 400 to 1, and signs of pollution were apparent for some distance down the stream. But in this case separate and intermittent discharges from two breweries in the neighbourhood provided a disturbing element, and the evidence must, therefore, be taken with some

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* Report of the Massachusetts State Board of Health, Discharge of Sewage into New York Harbour, 1911.

† Fifth Report, Appendix IV. p. 1 *et seq.*

TABLE B.

Showing Dilutions of Sewage Liquors with Clean (0·2) River Water required to prevent De-Oxygenation below 4·0 c.c. in Moderately Rapid and very Sluggish Reaches.

Depth of water in river (feet).	Time taken for river water to mix (hours).	Rate of re-oxygenation of mixture per hour expressed as per cent. of saturation.	Dilution required for:									
			1. Very good filter effluent taking up 0·1 part dissolved oxygen in 24 hours (0·5 part in 5 days).	2. Standard effluent taking up 0·5 part dissolved oxygen in 24 hours (2 parts in 5 days).	3. Bad effluent from filtration taking up 1·66 parts dissolved oxygen in 24 hours (5 parts in 5 days).	4. Weak precipitation liquor taking up 3·3 parts dissolved oxygen in 24 hours (10 parts in 5 days).	5. Average precipitation liquor taking up 5 parts dissolved oxygen in 24 hours (15 parts in 5 days).	6. Strong precipitation liquor taking up 6·7 parts dissolved oxygen in 24 hours (20 parts in 5 days).	7. Average septic tank liquor taking up 10 parts dissolved oxygen in 24 hours (20 parts in 5 days).	8. Average sewage taking up 13 parts dissolved oxygen in 24 hours (35 parts in 5 days).	9 Strong septic tank liquor taking up 16 parts dissolved oxygen in 24 hours (33 parts in 5 days).	10. Strong sewage taking up 20 parts dissolved oxygen in 24 hours (50 parts in 5 days).
2·5	1	0·99	0·4	2·0	7	14	20	30	40	55	66	85
	6	0·45	0·9	4·5	15	30	45	60	90	120	145	185
5·0	1	0·33	1·2	6·0	20	40	60	85	125	160	200	250
	6	0·15	2·5	13·5	45	90	135	150	275	360	440	550
10·0	1	0·12	3·0	17·0	60	115	170	233	340	450	560	700
	6	0·07	6·0	30·0	100	200	300	400	600	800	1,020	1,200

Note.—Saturation at 65° F. is taken as 6·63 cc. of oxygen per litre.

reservation. If we could isolate the effects of the sewage discharge, the dilution necessary to prevent nuisance would probably be not far short of 300 volumes. But for the reasons given above we think that a minimum dilution of 500 volumes where crude sewage is concerned would be a safer basis. In dealing with such cases the aggregate effect of the various pollutions which the river receives should be kept in view.

(*b*) *Reduction of Suspended Solids.*

39. While, as we have seen, dilution with a sufficient volume of clean water is capable of dealing satisfactorily with the dissolved impurities of sewage liquors, purification by this means of the suspended organic matters discharged into a stream is not as a rule rapid enough to forestall the cumulative effects of their deposition on the river bed. Nuisance is likely to arise from the accumulation of putrefying mud and the de-oxygenation of the water above it, unless the bed is cleansed intermittently by the scouring action of floods or continuously by the natural velocity of the current; and even in such cases the solids are not as a rule dispersed, they are merely transferred to some spot which is more favourable to their accumulation. We, therefore, attach great importance to the reduction of suspended solids in tank liquors to the lowest practicable figure, and we think that in all cases where such liquors are permitted to enter streams, standards for suspended solids should be prescribed and enforced.

40. Where the dilution is found sufficient to permit the discharge of a tank liquor into a stream, the dissolved oxygen absorption test might be dispensed with for the purposes of a standard. If the standard for suspended matter be fixed at such a figure as will ensure that the tanks are properly worked and regularly cleansed, improvement as regards the absorption of dissolved oxygen by the tank effluent will ordinarily follow.

41. We suggest that the standard of 6 parts of suspended matter per 100,000 should be adopted where the dilution, while not less than 150, does not exceed 300 volumes. To comply with this standard, chemical precipitation would be required unless the liquor were exceptionally weak. Where the dilution is more than 300 volumes, but less than 500, to prescribe the easier standard of 15 parts per 100,000, which could be satisfied by tank treatment without the aid of chemicals, might be permissible.

42. Where the dilution is so great, say, over 500 volumes, that no treatment is considered necessary, the standard would of course be in abeyance. But we think it of great importance, if only for the sake of the appearance of the river, that the grosser solids, such as undisintegrated fæces, paper, etc., should, as far as possible, be held back, and the provision of some effective form of screening apparatus should be insisted on wherever practicable. Settlement of grit and the heavier particles of suspended matter is also, in our opinion, very desirable. In some cases, no doubt, these requirements might involve a local authority in disproportionate expense, and it would be a question for the Superior Authority to determine what provision should be made in the circumstances of each case.

ON THE ADMINISTRATION OF STANDARDS.

43. We have in our previous reports recommended the constitution of a Central Authority and of separate Rivers Boards for different watersheds, and we wish to emphasize our view that for the proper conservation of our rivers and water supplies such an organisation is essential.

It would, no doubt, be possible to embody in a statute or in a statutory order of the Central Authority several standards and the precise conditions in regard to dilution which should determine the adoption of one of these standards.

Thus, when once the degree of dilution available for the discharge from the works of any local authority had been ascertained, that authority would be *ipso facto* liable to comply with the standard appropriate to that degree of dilution.

44. We think however that such a method of authoritative classification would be impracticable.

It is clear that degree of dilution, though undoubtedly one of the most important, is not the only factor on which the presence or absence of nuisance depends. The depth and velocity of the river, the uses to which it is put and the proximity of other sources of pollution, would need to be taken into account; and the Central Authority who would be called in to adjudicate on a dispute as to which of several standards should be imposed in a particular case might find themselves bound by the statute or their general order to give a decision which in all the circumstances they considered inappropriate.

45. It is desirable that the Rivers Board or Central Authority should not only consider the particular circumstances affecting each locality, but should be in a position to take a more or less comprehensive view of the river as a whole. It will be readily understood, for example, that while in the case of properly managed works a certain stage of purification can be reached at moderate expense, each higher degree of purification is apt to involve a more than proportionate increase of cost. On a comprehensive view, therefore, it is likely to be more economical to demand compliance with a moderate standard of purity on the part of a local authority situated on the higher reaches of a river, even though that standard be in excess of merely local requirements, than to give that authority the utmost relaxation that their circumstances will allow, if such relaxation would impose on a place lower down the stream an obligation which it could only meet at excessive cost. When considering a particular standard the Rivers Board or Central Authority should embrace in its view not only the river at the point where the discharge is received, but that stretch of the river which extends to the point where by natural self-cleansing processes the water has again recovered its former purity. If a river is found to be receiving in its course successive pollutions at intervals so short that it cannot recover itself by re-oxygenation, the conditions to be taken into account may extend as far as the tideway.

46. Again it may be desirable that the Central Authority, before allowing the discharge of crude sewage into a stream, should take into account the *total* volume of the sewage with its suspended matter as well as the *relative* volume (*i.e.*, as compared with the volume of the stream). Our experience shows that great dilution even to the extent of 1,000 to 1 in a rapid current does not altogether prevent local deposit of mud; and it is clearly possible that a large deposit may become at times offensive while a smaller one never obtrudes itself upon the senses, although the relative volume of the stream is the same in each case. How far nuisance is likely to be caused by such deposits will largely depend on the depth and velocity of the stream, the position of the outfall and other local conditions; but we think there may be circumstances in which sewage liquor, if large in volume, should not be permitted to carry the whole of its suspended matter into the river, even though the volume of the river be considerably more than 500 times larger.

We think, therefore, that it is of great importance that the Central Authority should be free to decide each case on its merits, and that a scale of standards prescribed by statute or by general order must on administrative grounds be abandoned.

47. In order to simplify administration the normal standard should be prescribed by Statute or by Order. This standard should apply to all sewage discharges into non-tidal waters, except where local circumstances are shown to the satisfaction of the Central Authority to justify a special standard.

Compliance with this standard should be obligatory in regard to all discharges of sewage into non-tidal waters, and should be enforced by the Rivers Boards as a matter of routine, except in cases where it is shown to the satisfaction of the Central Authority that in view of local circumstances it is expedient to prescribe either an easier or a more stringent standard. In such cases the Central Authority should be empowered to approve special standards to be enforced by the Rivers Boards in place of the general standard.

48. The Central Authority will naturally pay special attention to waters which are to be used for potable purposes, and in the case of such water, any application for alteration of the general standard would be closely scrutinized. The question of drinking water is so vitally important that we think it right to repeat the conclusions at which we arrived in our Fifth Report, and to which we adhere.

> "304. We observe that previous Commissions have reported that, of all the processes which were proposed for the purification of sewage, or of water polluted by excrementitious matter, there is not one which is sufficiently effective to warrant the use, for dietetic purposes, of water which has been so contaminated, and the 1868 Commission stated that, in their opinion, "rivers which had received sewage, even if that sewage had been purified before its discharge, were not safe sources of potable water.' We, therefore, conclude that the framers of the Rivers Pollution Prevention Act, 1876, did not contemplate that local authorities should be required so to deal with their sewage that the rivers into which the purified sewage flowed might be regarded as safe sources of water supply, in cases in which the water was not to be filtered before distribution.
>
> "305. In our opinion much the same position must be taken up to-day. Although the methods available for the purification of sewage are more numerous than when the 1868 Commission reported, our examination of a very large number of effluents from sewage farms, and from artificial filters of various kinds, shows that, although such effluents may be very good as judged by chemical and physical tests, they are generally liable to contain large numbers of micro-organisms of intestinal derivation, and that if such organisms are to be destroyed, or eliminated, the effluents must be subjected to some treatment additional to that which is ordinarily employed.

"We have carried out some experiments for the purpose of ascertaining the practicability of certain of the methods which have been suggested for the removal or destruction of these micro-organisms. These experiments, which are described in Dr. Houston's Report, Appendix IV., have shown that, while it would be practicable to render sewage effluents fairly pure, bacteriologically, the cost of the necessary additional treatment would be serious.

"306. Moreover, a false sense of security would be obtained by the adoption of such further treatment unless, at the same time, storm overflows on sewers were abolished.

"In the great majority of towns, sewers are provided with storm overflows, by which, in time of storm, large quantities of sewage are discharged into the river or stream untreated. Such discharges, we find, are frequently more impure, bacteriologically, than the normal crude sewage.

"In the opinion of some engineering witnesses whom we have called before us, it would generally be impracticable to dispense with storm overflows, but assuming, as an engineering possibility, that they could generally be dispensed with, it is quite clear that the necessary enlargement of the sewers would involve a very large outlay. In some towns, if there were no storm overflows, the effect of a storm would be to cause the flow in the sewers to be very many times the normal rate for a short period.

"307. By constructing a separate system of sewers for storm water the effect of storms on the other sewers would no doubt be greatly lessened, but if bacterial purity is to be required in the case of all discharges from sewers, it would be necessary to provide a second plant for the treatment of the liquids flowing in the storm water sewers, as these liquids are often exceedingly impure.

"The amount of liquid which would be brought down by such separate sewers would vary, according to local conditions, but during the course of a year it would probably be at least half as much as the volume carried by the other set of sewers.

"308. In our opinion, the cost of reconstructing the sewers so as to allow of the abolition of storm overflows, together with the cost of providing and maintaining purification plant which could be relied on at all times to render the total refuse waters of a town both chemically and bacteriologically pure, would in most cases be practically prohibitive; and further, even if this additional burden were placed on local authorities, the water of rivers would generally still require to be treated before it could be safely distributed for drinking purposes.

"309. We are satisfied that rivers generally, those traversing agricultural as well as those draining manufacturing or urban areas, are necessarily exposed to other pollutions besides sewage, and it appears to us, therefore, that any authority taking water from such rivers for the purpose of water supply must be held to be aware of the risks to which the water is exposed, and that it should be regarded as part of the duty of that authority, systematically and thoroughly, to purify the water before distributing it to their customers.

"310. Apart from the question of drinking waters, we find no evidence to show that the mere presence of organisms of a noxious character in a river constitutes a danger to public health or destroys the amenities of the river. Generally speaking, therefore, we do not consider that in the present state of knowledge, we should be justified in recommending that it should be the duty of a local authority to treat its sewage so that it should be bacteriologically pure."

SPECIAL STANDARDS.

49. The special standards should, in our opinion, be framed and selected upon the lines which we have indicated in regard to those cases where the general standard would not be applicable. But it is clearly desirable that the Central Authority in considering a claim for special treatment should have some discretionary powers, and we do not insist in the case of special standards upon strict adherence to the precise limits for suspended solids and to the precise scales of dilution which we have indicated. It is plain that the effect of dilution must depend not only upon the relative volumes of sewage liquor and river water, but also upon the rate at which they became completely mixed, and therefore such factors as the velocity of the stream and the position of the sewer outfall must also be taken into account.

On the other hand, we have thought it right to set out at some length the results at which we have arrived, in order that the adjustment of special standards to local requirements may proceed on a definite principle, and that differential treatment may not be open to the suspicion of caprice.

FURTHER OBSERVATIONS ON THE ADMINISTRATION OF STANDARDS.

50. In our Fifth Report we made the following recommendation:—

"316. We recommend that the Central Authority should determine the nature of the tests which are to be applied for the purpose of standards, and that it should be made the duty of the Rivers Board, or of the County Council, in areas not under the jurisdiction of a Rivers Board, to determine from time to time, subject to appeal to the Central Authority what standards should be adopted.

"317. In the first instance it would be convenient that the Central Authority should prescribe one standard for all non-tidal waters, in place of the existing statutory provisions. It would then rest with the Rivers Board or County Council to fix, subject to appeal to the Central Authority, a higher or lower standard, in any case in which they were of opinion that the circumstances required or justified a different standard."

* * *

"319. Power should be conferred on the Central Authority to suspend from time to time the operation of any standard, to allow time for the construction of works, or for any other reason, which, in their opinion, justified such suspension."

We now repeat this recommendation subject to one or two modifications suggested by our further consideration of the subject.

51. We have already set out in paragraph 22 above, what should be the normal standard.

As regards subsidiary standards we suggest that they should be prescribed in all cases by the Central Authority, not merely in cases of appeal from the decision of the Rivers Board or County Council. This procedure would secure greater uniformity of practice and would check any tendency to undue laxity which might manifest itself in watersheds not hitherto subject to efficient supervision.

52. We think it of importance that a standard once imposed upon a local authority should not be altered until the expiration of a definite period, in order that they may have some security as to the extent of their liability.

We suggest that these periods should be prescribed by Order of the Central Authority, and should in the case of the general or any specially stringent standard be not less than ten years from the date when the standards came into operation. In the case of relaxed standards the periods should be shorter. The less elaborate the plant required to meet a standard, the less hardship there will be in reducing the period during which the standard should remain in force; and on the other hand, it is desirable to offer the local authorities some inducement, in the shape of a more prolonged immunity from interference, to carry purification beyond the minimum. By the end of those periods the Central Authority should have acquired sufficient experience to enable them to decide whether the general standard required any modification (which we suggest they should be empowered to effect by the issue of an Order), and also to revise, where necessary, the special standards in particular cases.

53. The power to suspend the operation of a standard, to which we referred in paragraph 319 of our Fifth Report, quoted above, will require to be freely exercised when first the new machinery is set up. It will be the duty of each Rivers Board in the first instance, to prepare a scheme for the whole of their watershed. In preparing this scheme they will have to consider many claims for exceptional treatment some of which will, after local investigation, be found to justify the alteration of the general standard; while in other cases where such claims are either not made or are made and disallowed, the existing works will be found inadequate to meet the demands of the general standard. Time will obviously be needed for the settlement of these points and for the erection of new or the improvement of existing works.

54. On the other hand, a considerable number of local authorities will be found already provided with purification plant which is capable or might readily be made capable of meeting the requirements of the general standard. Of these it may be that some will desire to claim indulgence on the ground of the large dilution which their effluents receive; but we think that the superior authorities will rightly hesitate to countenance any relaxations which might involve discontinuing the use of existing works.

55. It will obviously be necessary for a Rivers Board in considering the needs of the watershed within their jurisdiction to proceed by degrees, and they may think it right to deal with pollutions occurring in the upper reaches of the river before attacking the problems presented by discharges occurring lower down.

We think that such a course is unnecessary, because the scheme on which our suggested standards are based, does not take directly into account variations in the quality of diluting water. And in many cases it would be undesirable in practice.

As a rule the areas draining into the head waters of a river are not densely populated, and consequently the pollutions derived from them, though they may be relatively large as compared with the volume of the small tributaries into which they discharge, occur at comparatively wide intervals, and do but little damage of a lasting character to the main stream. On the other hand, the pollutions arising from the larger centres of population, which are generally situated on the middle and lower reaches of a river, are not only more lasting in their effect, but owing to the extent of the requisite purification works, take longer to remedy.

We think, therefore, that the Rivers Board might be well advised to turn their attention first to securing compliance with the standard by the larger towns whose works were as yet inefficient. The smaller communities might meanwhile employ this period of grace either in making provision for a scheme of sewerage and sewage disposal which would be adequate for their increasing requirements, or, if their population were stationary or diminishing, in adopting some system of dry conservancy which would materially lessen the amount of pollution which entered the river.

REGULATIONS OF THE CENTRAL AUTHORITY.

56. The working of the machinery which we have suggested will be greatly simplified if the Central Authority draw up a code of instructions or regulations for the guidance of Rivers Boards and local authorities. This code should indicate the circumstances in which special standards would be permitted and should define, as far as practicable, the nature of those standards.

THE TAKING AND ANALYSIS OF SAMPLES.

57. We think it is desirable that local authorities discharging liquid refuse into streams should take periodical samples representative of the character of their effluent or sewage liquor, and should submit these samples to the tests required by the standard and to any other tests which may be prescribed by regulations of the Central Authority; and they should keep systematic records of the analytical results.

Facilities should also be provided for the inspection of these records by the Rivers Boards or Central Authority, and for the taking and testing of samples by those authorities. Sampling chambers should be provided in every case as near the outfall as questions of fall and other local conditions permit. These matters would be proper subjects for regulations by the Central Authority, which should also make provision in regard to the enforcement of standards, if necessary, by legal proceedings. We do not anticipate that a Rivers Board would ordinarily take proceedings on the strength of a single sample which failed to satisfy the standard; but we think it essential that they should be empowered to do so, in order to prevent occasional but wilful discharge of highly polluting matter by the improper use of bye-pass valves or overflows or by other surreptitious means.

GAUGING.

58. The volume of sewage liquor or effluent discharging into a stream is, as we have explained, a factor of the greatest importance in fixing the appropriate standard, and the regulations should provide for the tanks or other works being so constructed as to facilitate accurate gauging and drawing of average samples.

POWER OF ENTRY.

59. We think that the officers of the Central Authority and of the Rivers Boards should have statutory authority to enter upon lands at any time without notice for the purpose of inspecting works and rivers and taking samples of the liquor or effluent and river water wherever they can be obtained. The Rivers Pollution Prevention Act, 1876, contains no provision on this subject, but reference may be made to sections 16 and 17 of the Alkali Works Regulation Act, 1881, section 98 of the Thames Conservancy Act, 1899, and section 7 of the Middlesex County Council Act, 1906. In the Mersey and Irwell Joint Committee Act, 1892 (section 10) and the West Riding of Yorkshire Rivers Act, 1894, the power to take samples is limited to the point at which the effluent enters the stream. We think this limitation is undesirable.

STORM WATER SEWAGE.

60. We consider that the standards should not apply to storm water sewage. In regard to this matter we refer to paragraphs 292 to 295 of our Fifth Report, and we repeat our recommendations with regard to storm overflows and the treatment of storm sewage, the adoption of which would in our opinion prevent the occurrence of nuisance.

TIDAL WATERS.

61. In part VII. of our Fifth Report we summarised the position in regard to the pollution of estuaries and tidal waters (which we dealt with at length in our Fourth Report) and stated that we did not think it practicable to lay down fixed rules as regards a standard of effluent for tidal waters.

We do not now suggest that the general standard should apply automatically to tidal waters as in the case of non-tidal waters, but we think that the principle which we have recommended in regard to special standards for streams might usefully be applied to tidal waters where a standard is considered necessary.

SUMMARY OF CONCLUSIONS.

62. We may summarise our conclusions as follows :—

(a) The law should be altered so that a person discharging sewage matter into a stream shall not be deemed to have committed an offence under the Rivers Pollution Prevention Act, 1876, if the sewage matter is discharged in a form which satisfies the requirements of the prescribed standard.

(b) The standard should be either the general standard or a special standard which will be higher or lower than the general standard as local circumstances require or permit.

(c) **An effluent in order to comply with the general standard must not contain as discharged more than 3 parts per 100,000 of suspended matter, and with its suspended matters included must not take up at 65° F. (18·3° C.) more than 2·0 parts per 100,000 of dissolved oxygen in 5 days. This general standard should be prescribed either by Statute or by Order of the Central Authority, and should be subject to modifications by that Authority after an interval of not less than ten years.**

(d) **In fixing any special standard the dilution afforded by the stream is the chief factor to be considered. If the dilution is very low it may be necessary for the Central Authority, either on their own initiative or on application by the Rivers Board, to prescribe a specially stringent standard, which should also remain in force for a period of not less than ten years.**

(e) **If the dilution is very great the standard may, with the approval of the Central Authority, be relaxed or suspended altogether. Our experience leads us to think that as a general rule, if the dilution, while not falling below 150 volumes, does not exceed 300, the dissolved oxygen absorption test may be omitted, and the standard for suspended solids fixed at 6 parts per 100,000. To comply with this test no treatment beyond chemical precipitation would ordinarily be needed. If the dilution while not falling below 300 volumes does not exceed 500 the standard for suspended solids may be further relaxed to 15 parts per 100,000. For this purpose tank treatment without chemicals would generally suffice if the tanks were properly worked and regularly cleansed. These relaxed standards should be subject to revision at periods to be fixed by the Central Authority, and the periods should be shorter than those prescribed for the general or for the more stringent standards.**

(f) **With a dilution of over 500 volumes all tests might be dispensed with, and crude sewage discharged, subject to such conditions as to the provision of screens or detritus tanks as might appear necessary to the Central Authority.**

The Appendix to this Report, containing the results of the investigations made by our officers, will be published in a separate volume.

IDDESLEIGH, *Chairman.*
T. WALTER HARDING.
WILLIAM RAMSAY.
W. H. POWER.
T. J. STAFFORD.
R. A. TATTON.
F. J. WILLIS.

R. H. H. KEENLYSIDE, *Secretary,*
4th November, 1912.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

EIGHTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(Including any Liquid from any Factory or Manufacturing Process)

MAY PROPERLY BE ADOPTED.

STANDARDS AND TESTS FOR SEWAGE AND SEWAGE EFFLUENTS DISCHARGING INTO RIVERS AND STREAMS.

VOL. II.—APPENDIX.

By Dr. G. McGOWAN, Mr. C. C. FRYE and Mr. G. B. KERSHAW.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE
By WYMAN and SONS, Limited, Fetter Lane, E.C.

To be purchased, either directly or through any Bookseller, from
WYMAN and SONS, Limited, Fetter Lane, E.C., and 32, Abingdon Street, S.W.,
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1913.

[Cd. 6943.] *Price 2s. 9d.*

ROYAL COMMISSION ON SEWAGE DISPOSAL.

REPORT

TO THE

Commission on the Results of Streams Observations carried out during the Years 1909 to 1912 by

Dr. G. McGOWAN,

Mr. COLIN C. FRYE,

and

Mr. G. B. KERSHAW.

MARCH, 1913.

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ROYAL COMMISSION ON SEWAGE DISPOSAL.

PART I.

GENERAL PREFACE.

This Appendix embodies the facts upon which are based the recommendations of the Commission as set out in their Eighth Report. Since many of the questions involved are highly technical, and since the more important of them are dealt with in separate sections of the Appendix, it may be advisable to say a few introductory words of guidance.

Hitherto sewage effluents have been frequently designated as polluting or non-polluting, merely because they gave certain figures of analysis when submitted to particular laboratory tests.

Sometimes, it is true, there has been reference to the effect of the effluent on the ditch or stream receiving it, but, as a general rule, the effluent has been judged on the figures of analysis only.

In making these stream observations we have endeavoured to correlate actual effects produced by the discharge of sewage liquors or effluents into streams, with the results of chemical analysis, making the stream itself the ultimate arbiter in the matter.

As the result of this work, we have come to the conclusion that the 5 days' dissolved oxygen absorption test, taken along with the test for solids in suspension, is the best to apply when standards of purity are in question.

In Part I. of this Appendix the results of the observations at each place are fully set out for reference.

Part II. begins with a separate section dealing with the relative merits of various tests as correlated with riverside observations; immediately following that section are others (No. 2 and 3) which give in detail the methods of carrying out the two selected tests.

In Sections 4 and 5 the results of the observations upon the discharge of sewage liquors and effluents into streams are brought together and discussed, conclusions being given at the end of each as to the "limiting dilutions" indicated for liquors and effluents of given strength.

Section 6 deals with the question of limiting figures of impurity for river waters, and Section 9 with the collection of samples which are to be submitted to the proposed standard tests, together with the procedure to be adopted before analysis.

Sections 7 and 8 treat of the composition and properties of aquatic plants and river muds; Sections 10 and 11 with the position of sewage and effluent outfalls and the methods adopted for the gauging of rivers.

In Part III. are set out the results of the channel experiments. Since these bear on the correlation of tests with riverside observations and on the limiting figures of impurity, Part III. should be studied in conjunction with Sections I and 6 of Part II.

PRELIMINARY.

The Secretary, having been directed by the Commission, wrote to all the County Medical Officers of England and Wales, and also to the various Rivers and Conservancy Boards, asking to be notified of examples of the discharge of crude sewage, tank liquors or effluents into clean streams.

From the lists sent in reply to this letter some fifty rivers and streams were selected for a preliminary inspection, which was undertaken by Mr. G. B. Kershaw, Engineer to the Commission, and completed in the autumn of 1908.

As a result, twenty-five places were selected as affording suitable facilities for observation.

The actual observations upon the selected places began in August, 1908, with an examination of the River Avon from Rugby to Stratford.

After an interim report on the work had been placed before the Commission in the spring of 1910, attention was specially concentrated upon some sixteen of the twenty-five places.

The observations ended in June, 1912.

side
vations.

As a general rule, the riverside observation comprised the drawing of "corresponding" samples of river water, with a sample also of the sewage, tank liquor or effluent, which constituted the discharge, the estimation of the dissolved oxygen in the water, an examination of the banks and bed of the river, and an examination of the water as regards algae, plants, insects, fish, etc. A rough estimate of the river flow was made on every occasion.

ling of the
Water.

From two to six samples of river water were drawn by us on the occasion of each visit, one sample being drawn above the sewage outfall, and the others below.

The samples were sent off to the laboratory at Ealing by passenger train on the evening of the day upon which they were drawn. With a few exceptions, they arrived at Ealing the following morning.

Half-Winchester bottles, holding about 1,300 to 1,450 c.c. were used throughout.

As a general rule, sampling was done from the bank, the points of sampling being selected with great care, so as to draw from the main current of the stream. If this current could not be reached from a projecting bank on the outside of a bend in the river, dipping with a small bucket or wading was resorted to. On four of the rivers, namely, the Ouse, the Derwent, the Avon and the Cam, the samples were usually drawn from a boat.

In order to ensure as good correspondence as possible between the water samples of a given reach of river, a quantity of fluorescine, varying from 2 to 8 ozs., dissolved in dilute alkali, was usually added to the discharging sewage, tank liquor or effluent just after the sample of this had been taken. The green coloured water was then followed down stream.

By this means we were also able to watch the process of mixing of the sewage liquor and the river water, and to ascertain when it became complete.

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Sampling of the Sewage or Effluent Discharge.

The sample of sewage, tank liquor or effluent constituting the discharge was drawn either at the outfall itself, or, if this was impracticable, at a manhole as near the outfall as possible. In two cases, Pickering and Ollert it was impossible in some states of the rivers to obt true samples of the crude sewage discharged.

Quantities of River Water taken for Analysis.

In the analysis of the river waters, 100 or 200 c.c. were usually taken for the determination of ammoniacal and albuminoid nitrogen (according to the result of an approximate preliminary test made by adding Nessler reagent to the water); 25 to 50 c.c. for nitrous nitrogen; 10 to 25 c.c. for nitric nitrogen; and 100 c.c. for "oxygen sorbed" from $\frac{N}{80}$ permanganate.

The methods followed for determining dissolved oxy absorption and suspended solids are fully detailed Sections 2 and 3, Part II., of this Report.

Estimation of the Dissolved Oxygen in the Water.

At the commencement of the observations in 1908, the Cuprous Chloride method, devised by Ramsay and Homfrey, was used for estimating at the riverside the dissolved oxygen in the water. It worked satisfactorily with waters which were colourless or nearly so, but with waters tinted yellow or brown the comparative readings could not be relied on. The apparatus for conducting the test was enclosed in a small box, so constructed that it could be carried by one person, along with two baskets each containing the three half Winchester bottles, to be used for the ordinary samples. Each basket when full weighed about 20 lbs., and the apparatus box about 10 lbs. In 1909, following Mr. Halliwell of the Ribble Committee, we adopted the modified Winkler method, already in use in the laboratory, for riverside work.

The box containing the apparatus for this was necessarily larger and heavier than that required for the Ramsay-Homfrey method; it weighed approximately 17 lbs. For this reason it could not be carried comfortably with the two baskets. In this case, therefore: (1) Help to be requisitioned; or (2) only one basket carri or (3) the small dissolved oxygen sample bottles, contain about 1 c.c. of sulphuric acid, carried in the pock The capacity of these small dissolved oxygen sam bottles was from 170 to 200 c.c. When plan (3) was lowed, the test was carried out at the hotel.

From the summer of 1911 to the end of the observatic the small dissolved oxygen sample bottles, contain 1 c.c. of strong sulphuric acid, were usually filled at river and then sent to Ealing for examination along w the large samples of river water. The object of add this small quantity of acid was to sterilize the water effluent, or at all events to inhibit the action of the bacte and so prevent absorption of dissolved oxygen.

The following table gives the volume of oxygen, in per litre, which 100,000 volumes of water will hold solution under ordinary conditions at temperatures fr 0° to 20° C. (32° to 68° F.).

Degrees Centigrade.	Degrees Fahrenheit.	c.c. of oxygen held in solution by 1 litre of water (Winkler.)	Degrees Centigrade.	Degrees Fahrenheit.	c.c. of oxygen held in solution by 1 litre of water (Winkler.)
0	32·0	10·2	11	51·8	7·7
1	33·8	9·9	12	53·6	7·5
2	35·6	9·6	13	55·4	7·3
3	37·4	9·4	14	57·2	7·2
4	39·2	9·1	15	59·0	7·0
5	41·0	8·9	16	60·8	6·9
6	42·8	8·7	17	62·6	6·8
7	44·6	8·5	18	64·4	6·6
8	46·4	8·3	19	66·2	6·6
9	48·2	8·1	20	68·0	6·4
10	50·0	7·9			

At a temperature of about 60° F. clean river water may be taken as containing about 7 c.c. of oxygen per litre, or 1 part by weight of oxygen per 100,000 parts of water.

Examination of the Bed and Banks of the River.

Much information as to the normal quality of the water of a river can be obtained by the examination of its bed and banks.

Stones from the shallows were always examined for algal growth, water insects, etc., and particular attenti was paid to deposits of mud in the pools and on ban caused by eddies. In special cases, samples of mud we dredged up and sent to Ealing for examination.

Algae, Plants, Insects, and Fish.

Algae.—Much attention was paid to grey and green algal growths.

Whenever any alga of uncommon appearance was observed, or when algae were present in unusual quantities, specimens were collected and sent to the Royal Botanic Gardens, Kew, for identification. As this involved examination of a number of specimens, the Commission are greatly indebted to the Director, Sir David Prain, F.R.S., for his courtesy in the matter.

Water plants.—Any water plants of doubtful species e.g., some of the pond weeds) were also referred to Kew for naming purposes. Most of the species met with in quantity, *e.g.*, *Ranunculus Aquatilis* (Water Crowfoot) and *Anacharis Alsinsastrum* could not well be mistaken, and were easily identified at sight.

Insects, etc.—The commoner insects, such as *gyrin natator*, *notonecta glauca*, *hydrometra stagnorum*, a *gerris gibbifera* were noted when present, as were a water shrimps, thread worms (nematoids), larvæ, et when these occurred in any quantity.

Fish life.—The absence or presence of fish life w noted as far as this was practicable, and information the subject was also obtained whenever possible fro local fishermen. It must, however, be noted that so of the coarse fish, *e.g.*, tench and bream, are not oft seen in the daytime, and their presence in sluggish strea may, therefore, easily be overlooked.

The fish chiefly observed were trout and grayling, da roach, rudd, chub, pike and eels, and, of the smaller fis sticklebacks and minnows.

Gaugings.

Careful gaugings of the rivers were made from time to time, chiefly in the drier months of the year.

The principal methods of gauging were as follows:—

(1) Cross section and current meter;
(2) Cross sections and floats;
(3) Temporary dam and rectangular weir;
(4) Measurement of flow over existing weirs.

Details of methods of gauging used are given in Part I Section 11 of this Report.

The height of the river was marked at each gaugi so that on a subsequent visit by any other Officer of t Commission it was possible to arrive at a rough estima of the volume of the river at that time.

t Velocities.

The mean current velocities* have been roughly differentiated, as follows :—

From 20 feet per minute, downwards	sluggish to very sluggish.
,, 20 to 40 feet per minute	slow.
,, 40 to 60 ,, ,,	moderate.
,, 60 to 100 ,, ,,	rapid.
Over 100	very rapid.

It must not, however, be forgotten that even the most sluggish river may become very rapid in times of flood, exercising a large scouring effect on the bed of the stream.

al Variations.

Our colleague, Dr. Houston, throughout laid stress upon the importance of taking account of the seasonal variations which take place in a river.

When the winter is past and the water grows warmer, rushes, reeds, and other fixed plants shoot up from the muddy bed, water lilies throw out new fronds, while floating plants and green algal growths develop with great rapidity. Insect and bacterial life also increase to a marked extent at the same time. As a result of this development of bacterial, plant, and animal life, the river water undergoes many changes. The plants and algae abstract ammonia and nitrate from the water, and the life processes of the bacteria result in the more rapid absorption of dissolved oxygen. The processes tending towards self-purification of the water thus operate most strongly when the water is warm. In the autumn of the year, as the water becames colder, the plants and algae tend to decay and to be washed down stream by the rains, while the insect life diminishes. The bed of the river is thus cleared of much obstruction, and the increased flow of water, finding for itself new channels in the mud, scours away much of the vegetable *débris* accumulated there, and deposits it in pools or on flood-meadows or in the river estuary, as the case may be.

During the winter, the river water frequently contains much oxidizable matter (chiefly in suspension) brought down by the floods, and the living agencies, which make for purification, are then at their lowest ebb owing to the low temperature of the water. On the other hand, at this time of year, the dissolved impurities are often much diluted by the rainfall, and the activity of bacteria may be so restrained as to retard those processes which, although finally making for purification, temporarily cause deoxygenation of the water and possible nuisance from smell. The most noticeable signs of pollution, namely, grey and green algal growths, are not subject to seasonal change in the same degree as is the ordinary plant life of a clean river.

In polluted water, grey algae appear to flourish the whole year round, and green algae never disappear altogether from streams which favour their development.

In observing the condition of a river from the point of view of pollution, it is thus desirable to include the winter as well as the summer months, and this course has been followed by us.

It should be added, however, that most of our observations have been made in the warm, or at any rate, the dry months of the year during minimum flow of rivers.

ical Work
sistance.

The analytical work in connection with these stream observations has been carried out by :—

Mr. E. H. Richards, B.Sc., F.I.C.
Mr. A. C. Carter, F.I.C.
Mr. A. F. Girvan, B.Sc., (now assistant in the laboratory of the Metropolitan Water Board).
Mr. W. G. Winterson, B.Sc., (since deceased).
Mr. E. C. Barfield, B.Sc.
Mr. G. T. P. Tatham, B.Sc.,

either now or formerly assistant chemists to the Commission.

Besides carrying out the daily work in the laboratory, these gentlemen have helped to improve analytical processes, and have suggested lines of investigation as the work proceeded, while without their willing co-operation it would have been almost impossible to have collated all the results and to have drawn the proper deductions from them.

In the death of Mr. W. G. Winterson, after he had been associated with us in the work of the Commission for several years, we lost not only an able colleague but a friend, for apart from the great merit of his work he had endeared himself to us all.

We are indebted to our former colleague, Mr. R. D. Littlefield, for drawing nearly all the samples from the South Delph at Lincoln, and making the riverside observations there.

Mr. W. Hollingsworth, clerk to the Commission, has rendered us great help with the clerical work in connection with this Report. We should like to take this opportunity of acknowledging our indebtedness to him.

With the consent of their respective authorities, the following gentlemen were kind enough to carry out for the Commission, in 1911, a number of analyses, including the determination of dissolved oxygen absorption by sewage liquors and effluents :—

Name.	*Authority.*
Mr. J. Boothman	Accrington and Church Joint Sewerage Board.
Mr. F. R. O'Shaughnessy, A.R.C. Sc., F.I.C.	Birmingham Tame and Rea District Drainage Board.
Mr. H. R. Pickard, Ph.D., F.I.C.	Blackburn Corporation.
Mr. John H. Wright	Bradford City Corporation.
Mr. Raymond Ross, F.I.C.	Burnley Corporation.
Mr. Joshua Bolton	Bury Corporation.
Mr. W. D. Scouller, B.Sc.	Chester City Corporation.
Prof. A. Bostock Hill, M.D., F.I.C.	Coventry City Corporation.
Mr. John E. Farmer	Croydon Corporation.
Mr. T. E. Wood	Halifax Corporation.
Mr. W. H. Speight	Huddersfield Corporation.
Mr. J. T. Thompson, M.Sc.	Leeds City Corporation.
Mr. S. F. Burford	Leicester Corporation.
Mr. G. J. Fowler, D. Sc., F.I.C.	Manchester City Corporation.
Mr. W. L. Sutton, F.I.C.	Norwich City Corporation.
Mr. S. Urmson	Oldham Corporation.
Mr. W. W. Fisher, M.A., F.I.C.	Oxford City Corporation.
Mr. J. H. Kershaw	Rotherham Corporation.
Mr. J. Carter Bell, A.R.S.M., F.I.C.	Salford Corporation.
Mr. John Haworth	Sheffield City Corporation.
Mr. J. T. Hall	Staines Urban District Council.
Mr. H. T. Wrigby, F.I.C.	Stoke-upon-Trent Corporation.
Mr. H. D. Bell	Stratford-on-Avon Corporation.
Mr. W. Clifford, A.M.I.C.E.	Wolverhampton Corporation.

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* These velocities are not to be confused with the maximum central velocities.

We are specially indebted also to a number of local officers, usually the engineers and sewage works managers, at those places which were selected for observation or from which we obtained samples at different times. These gentlemen afforded us help which we could hardly have dispensed with.

Their names are as follows :—

Name.	*Authority.*
Mr. H. Sheldon, surveyor	Alderley Edge, Urban District Council.
Mr. W. Bennett, surveyor	Barnoldswick Urban District Council.
Mr. E. H. Adey, surveyor	Berkhamsted Urban District Council,
Mr. W. H. Grieves (observations, 1908–10) surveyors	Buxton Urban District Council.
Mr. F. Langley (,, 1911–12) surveyors	
Mr Julian Julian, borough surveyor	Cambridge Corporation.
Mr. Henry Smith, sewage farm manager	
Mr. Cuthbert Brown, A.M.I.C.E., borough surveyor	Chelmsford Corporation.
Mr. W. S. Shell, surveyor	Consett Urban District Council.
Mr. J. E. Swindlehurst, M.I.C.E., city surveyor	Coventry City Corporation.
Mr. W. Main, sewage farm manager	
Mr. Charles Jones, M.I.C.E., borough surveyor	Ealing Corporation.
Mr. Ed. Basley, sewage works foreman	
Mr. W. A. Nicholson, surveyor	Halstead Urban District Council.
Mr. L. L. Warren, sewage and water works manager	Hartley Wintney Rural District Council.
Mr. S. S. Grimley, M.I.C.E., surveyor	Hendon Urban District Council.
Mr. J. G. Choat, sewage works manager	
Mr. E. Borrisow, surveyor	Huntingdon Corporation.
Mr. Sholto Douglas, surveyor	Kenilworth Urban District Council.
Mr. R. A. MacBrair, M.I.C.E., city engineer	Lincoln City Corporation.
Mr. A. Applewhite, sewage works manager	
Mr. R. Richardson, surveyor	Malton Urban District Council.
Mr. R. Brown, surveyor	Barnard Castle Rural District Council.
Mr. F. C. Cook, A.M.I.C.E., borough surveyor	Nuneaton Corporation.
Mr. Wm. Spink, surveyor	Pickering Urban District Council.
Mr. D. G. Macdonald, A.M.I.C.E., surveyor	Rugby Urban District Council.
Mr. John Edey, surveyor	St. Neots Urban District Council.
Mr. H. J. Hamp, A.M.I.C.E., borough surveyor	Swindon Corporation.
Mr. J. Siddalls, borough surveyor	Tiverton Corporation.

In concluding this preliminary note, we would desire to say that throughout the preparation of this Report we have had the great benefit of Sir William Power's counsel and advice.

In expressing our warm personal gratitude to him it seems almost unnecessary to add how greatly our work has been assisted by his wide experience and constructive criticism.

We must also add with regard to our colleague Dr. A. C. Houston, that although his name does not appear as one of the signatories to this Report, we have frequently consulted him and have been greatly helped by his criticism.

(*Signed*) George McGowan.
Colin C. Frye.
G. Bertram Kershaw.

March, 1913.

ALDERLEY EDGE AND THE MOBBERLEY BROOK.

Population.—2,950.
Sewerage System.—Combined.
Dry weather Flow.—100,000 gallons per 24 hours.
Nature of Sewage.—Water closet domestic, rather weak.
Treatment.—Settling tanks, streaming filters and artificial land plots. The storm water is treated upon land.

Detritus Tank - - - - - -	15,000 gallons.
Settling „ - - - - - -	120,000 „
Total - -	135,000 „

Total cubic content of filters - - 4,033 yards.

Total irrigable area of land - -	For ordinary flow - -	2 acres
	For storm flow - - -	3 „
	Total - -	5 „

Effluent.—The effluent is, as a rule, a slightly opalescent liquid of brownish tint, with an earthy smell. On occasion, however, it is putrescible upon incubation.

It contains, on the average, about 3·0 parts per 100,000 of suspended matter.

It gave the following average figures, among others:—

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	0·73
Nitric nitrogen - - - - - - -	0·48
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. (27° C.)- - - - - -	1·19
Dissolved oxygen taken up from water at 65° F. (18·3° C.):—	
In 48 hours - - - - - - - -	0·40
In 5 days - - - - - - - -	1·46

Name of Stream.—The Mobberley Brook, a tributary of the River Bollin.

Velocity.—The mean velocity of the current, as measured in fairly dry weather over a stretch of about 1 mile was about 66 feet per minute. The current may, therefore, be considered fairly rapid.

The brook is from 8 to 12 feet wide, and varies from a few inches to about 3 feet in depth.

The flow in dry weather is about 900,000 gallons per 24 hours, so that the dilution of the effluent at such times is about 9 to 1. In wet weather the volume of water in the brook is much increased. A rate of flow of over 7,000,000 gallons has been measured.

Effects of Effluent Discharge.—Visits paid in February, June and October, 1909, July and October, 1910, and February and May, 1911.

The effect of the discharge is slightly to deteriorate the appearance of the brook for a stretch of about a mile but no farther. Twigs and stones are covered with a loose brown deposit, and some grey growth is generally present.

No nuisance from smell was observed and there were no signs of offensive deposit.

Samples drawn.	Approximate dilution of effluent with brook water.		River water just above outfall.	Sewage effluent	River water 50 yards below outfall.	River water 1,700 yards below outfall.	River water 2,600 yards below outfall.	River water 3,800 yards below outfall.
eb. 25, 1909.	9 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·043	0·98	—	0·29	0·20	0·29
		Albuminoid nitrogen - - - - - - - - -	0·03	0·14	—	0·04	0·03	0·06
		Nitric nitrogen† - - - - - - - - - -	0·18	0·56	—	0·26	0·29	0·27
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·30	0·45	—	0·43	0·43	0·52
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·80	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·15	1·16	—	0·59	0·42	0·53
		Chlorine - - - - - - - - - - - -	2·29	7·99	—	3·68	3·46	3·60
		Suspended solids - - - - - - - - - -	—	2·4	—	3·4	2·8	2·6
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	1·22	0·44	—	1·05	1·12	1·01
une 22, 1909.	60 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·144	0·520	—	0·192	—	—
		Albuminoid nitrogen - - - - - - - - -	0·28	0·15	—	0·28	—	—
		Nitric nitrogen - - - - - - - - - -	0·19	0·32	—	0·21	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	3·63	1·36	—	2·94	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·58	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	2·72	2·43	—	2·36	—	—
		Chlorine - - - - - - - - - - - -	2·23	3·92	—	2·60	—	—
		Suspended solids - - - - - - - - - -	69·2	13·6	—	45·6	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·15	0·00	—	0·13	—	—

† Nitrous Nitrogen was also tested for in the samples of river water, but it was rarely present in appreciable quantity.

Samples drawn.	Approximate dilution of effluent with brook water.		River water just above outfall.	Sewage effluent	River water 50 yards below outfall.	River water 1,700 yards below outfall.	River water 2,600 yards below outfall.	River wate 3,800 yards belo outfal
Oct. 15, 1909.	27 to 1	Ammoniacal nitrogen	0·074	0·230	0·101	0·107	0·086	—
		Albuminoid nitrogen	0·09	0·06	0·10	0·12	0·12	—
		Nitric nitrogen	0·12	0·36	0·13	0·16	0·12	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	1·67	0·54	1·90	1·63	1·94	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·79	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	1·02	0·58	0·82	0·70	0·62	—
		Chlorine	1·77	4·00	1·81	1·88	1·73	—
		Suspended solids	16·5	2·8	15·5	13·8	24·1	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·51	0·14	0·49	0·43	0·41	—
July 20, 1910.	18 to 1	Ammoniacal nitrogen	0·023	0·685	0·274	0·194	—	—
		Albuminoid nitrogen	0·03	0·11	0·06	0·04	—	—
		Nitric nitrogen	0·15	0·25	0·31	0·26	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·40	0·90	0·45	0·38	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·93	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·16	1·52	0·43	0·42	—	—
		Chlorine	2·37	8·98	4·71	4·50	—	—
		Suspended solids	1·9	4·6	1·8	0·7	—	—
		Oxygen in solution when drawn	0·86	0·26	0·57	0·46	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·84	0·09	0·49	0·52	—	—
Oct. 6, 1910.	9 to 1	Ammoniacal nitrogen	0·020	0·670	0·188	0·183	0·096	—
		Albuminoid nitrogen	0·02	0·06	0·05	0·03	0·03	—
		Nitric nitrogen	0·13	0·11	0·13	0·14	0·19	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·52	0·48	0·54	0·49	0·53	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·79	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·11	0·34	0·16	0·21	0·39	—
		Chlorine	2·14	7·17	3·86	3·89	3·84	—
		Suspended solids	1·0	1·5	1·3	0·7	1·8	—
		Oxygen in solution when drawn	0·83	0·32	0·67	0·57	0·65	—
		Oxygen in solution when analysed, *i.e.*, after 6 days	0·81	0·07	0·49	0·53	0·64	—
Feb. 21, 1911.	20 to 1	Ammoniacal nitrogen	0·122	0·256	0·196	—	—	—
		Albuminoid nitrogen	0·07	0·05	0·19	—	—	—
		Nitric nitrogen	0·15	0·47	0·18	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	1·56	0·53	2·75	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·93	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·65	0·27	2·11	—	—	—
		Chlorine	2·00	5·65	2·02	—	—	—
		Suspended solids	7·2	2·1	19·3	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·85	0·70	0·57	—	—	—
May 30, 1911.	9 to 1	Ammoniacal nitrogen	0·018	0·960	0·360	0·307	0·162	0·144
		Albuminoid nitrogen	0·03	0·16	0·07	0·05	0·05	0·04
		Nitric nitrogen	0·19	0·07	0·14	0·15	0·29	0·54
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·40	0·85	0·52	0·44	0·49	0·54
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·56	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·31	0·93	0·94	1·05	0·65	0·58
		Chlorine	2·55	9·15	5·15	4·87	4·32	4·10
		Suspended solids	1·8	2·0	2·8	1·8	1·8	3·1
		Oxygen in solution when drawn	0·79	0·11	0·52	0·43	0·51	0·44
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·76	0·19	0·31	0·40	0·54	0·51

The water samples drawn in June, 1909, and February, 1911, were affected by storm sewage.

Summary.—1. The effluent did not give rise to any nuisance from smell when diluted with nine times its own volume of fairly clean water moving in a fairly rapid current.

2. The water was materially deoxygenated by the effluent.

3. There was no objectionable deposit of mud, but the general appearance of the brook for about a mile below the outfall was not good.

4. Grey growth was present in small quantity for about a mile below the outfall.

5. No fish were seen in the stretch of water under observation.

BARNOLDSWICK AND THE STOCK BECK.

Population.—7,141.
Sewerage System.—Partially separate.
Dry weather Flow.—150,000 gallons per 24 hours.
Nature of Sewage.—Domestic, mainly slop water.
Treatment.—Precipitation, continuous flow settlement and land filtration. The area of land was too small to give good purification, besides being of rather unsuitable character. The land plots are nearly always flooded.

Total combined tank capacity - - - - -	102,000 gallons.
Area of irrigable land - - - - - -	3·75 acres.

Note.—The observations at Barnoldswick refer to the year 1909 only, since that time percolating filters have been installed.

Effluent.—This was only partially purified and was more of the nature of a weak sewage, It was a dark, turbid liquid, with an offensive smell, and contained about 10 parts of suspended solids on the average.

It gave the following average figures, among others :—

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	3·58
Nitric nitrogen - - - - - - -	0·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	4·73
Dissolved oxygen taken up from water at 65° F. :	
In 48 hours - - - - - - -	9·7
In 5 days - - - - - - - -	14·7

Name of Stream.—The Stock Beck, a small tributary of the Ribble.

Velocity.—The current velocity, as measured in fairly dry weather over a distance of about 3,400 feet below the outfall, was 56 feet per minute. It is thus moderately rapid.

The beck is about 8 to 15 feet wide, and varies from a few inches to 2 feet 6 inches in depth.

The flow may be very much swollen in storm times.

The dilution of effluent in fairly dry weather is about 10 to 1.

The volume of water in the beck (about 1½ million gallons) is subject to artificial variations, the water being used for mills above the outfall. This also renders the water rather warm at times (highest temperature noted on visits, 18° C. (64° F.), in July, 1909).

Effect of Effluent Discharge.—Visits paid in May, July and October, 1909.

For about half a mile below the outfall there was an objectionable smell from the water in May and July; in October no smell was observed. On all three occasions the bed of the beck was fouled with black mud for at least half a mile. Grey fungus was present in abundance. Green growths only began to show at 1,000 yards below the outfall, *i.e.*, at the junction with Hell Forest Dyke.

From that point the condition of the beck showed progressive improvement. At Monk and Horton bridges (3,933 and 4,300 yards below outfall) trout were seen, and at Gisburn Park (10,700 yards below outfall), except for froth and brown deposit on stones, there were no sensible signs of pollution.

Samples drawn.	Approximate dilution of effluent with beck water.		River water just above outfall.	Sewage effluent	River water 200 yards below outfall.	River water 870 yards below outfall.	River water 4,250 yards below outfall.	River water 10,700 yards below outfall.
May 13, 1909.	10 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·002	3·980	0·580	0·214	0·214	0·064
		Albuminoid nitrogen - - - - - - - - - -	0·02	0·58	0·12	0·05	0·04	0·03
		Nitric nitrogen - - - - - - - - - - -	0·10	—	0·08	0·04	0·11	0·18
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·17	3·17	0·58	0·35	0·30	0·26
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	5·86	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·18	21·4	1·59	0·48	0·41	0·30
		Chlorine - - - - - - - - - - - - -	1·24	6·66	2·10	1·60	1·73	1·80
		Suspended solids - - - - - - - - - -	—	12·5	3·3	—	—	—
		Oxygen in solution when drawn - - - - - - -	0·97	0·07	0·80	0·81	1·19	1·04
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	1·25	0·00	0·17	0·91	1·50	1·24
July 2, 1909.	10 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·003	5·64	0·507	0·829	0·657	—
		Albuminoid nitrogen - - - - - - - - -	0·03	0·47	0·12	0·09	0·07	—
		Nitric nitrogen - - - - - - - - - - -	0·09	—	0·07	0·02	0·02	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·26	3·32	0·73	0·50	0·56	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	5·27	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·10	12·65	0·85	0·51	0·25	—
		Chlorine - - - - - - - - - - - - -	1·00	7·57	2·30	2·08	1·91	—
		Suspended solids - - - - - - - - - -	0·45	6·4	5·2	—	—	—
		Oxygen in solution when drawn - - - - - - -	1·06	0·25	1·02	0·97	1·02	1·10
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	0·87	0·00	0·00	0·00	0·00	0·00
Oct. 28, 1909.	20 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·008	2·020	0·112	0·084	0·074	0·02
		Albuminoid nitrogen - - - - - - - - - -	0·01	0·27	0·03	0·03	0·02	0·01
		Nitric nitrogen - - - - - - - - - - -	0·14	—	0·13	0·11	0·12	0·11
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·16	1·19	0·20	0·22	0·25	0·20
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·92	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·10	6·10	0·26	0·27	0·25	0·10
		Chlorine - - - - - - - - - - - - -	1·08	4·49	1·21	1·23	1·24	1·15
		Suspended solids - - - - - - - - - -	—	5·8	1·5	—	—	—
		Oxygen in solution when drawn - - - - - - -	1·05	0·22	1·02	0·98	1·02	1·11
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	1·09	—	0·95	0·92	1·04	1·08

Summary.—1. This effluent, or rather slightly purified precipitation liquor, when diluted with about 10 times its own volume of clean water moving in a moderately rapid current, gave rise to smell for a distance of half a mile.

2. Owing to the fairly rapid current and the shallowness of the stream the water was not much deoxygenated.

3. The bed of the beck was fouled for at least half a mile with a deposit of black mud.

4. Grey fungus was present in abundance for half a mile or so below the outfall, when it was replaced by green growth also in great abundance.

5. No fish were seen for a distance of a mile and a half below the outfall. Beyond this trout were plentiful.

BERKHAMSTED AND THE GRAND JUNCTION CANAL.

Population.—8,000 (approximately).
Sewerage System.—Partially separate.
Dry weather Flow.—500,000 gallons per 24 hours.
Nature of Sewage.—Water closet domestic.
Treatment.—Closed septic tanks followed by double contact beds. Storm water is treated upon land.

Total tank capacity	218,375 gallons
Total cubic content of contact beds	5,688 yards.

Effluent.—This is an opalescent liquid with a brownish tint, and containing, on the average, about 3 parts of suspended matter. As a general rule, but not always, it has a clean smell. It is of variable quality and composition.

On two occasions out of seven it putrified on incubation.

	Parts per 100,000.
Ammoniacal nitrogen	0·80
Nitric nitrogen	0·35
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·01
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	0·81
In 5 days	1·49

Name of Stream.—The Grand Junction Canal, which is fed at Berkhamsted with water from the River Bulbourne.

Velocity.—The effluent is discharged at the head of a pound between two locks, 750 yards apart. In this pound the velocity of the current is entirely dependent upon the opening of the locks. Each time a lock is opened there is a current velocity of about 7 feet per minute for some 30 minutes. Between the lock openings the water is practically stagnant.

The dilution of the effluent in the pound naturally varies from hour to hour, but on the average it may be put at about 4 to 1.

The width of the canal pound is about 30 to 35 feet, and the depth of the water in the centre is about 6 feet.

The canal water usually contains a good deal of finely divided suspended matter, owing to the disturbance caused by the boats and the opening of the locks.

Effect of Effluent Discharge.—Visits paid in April, August and November, 1909, January and June, 1910, and February and June, 1911.

The water from the pound had a stale wormy smell on shaking, but there was no smell on the tow-path.

Much grey growth was present on the grass at the sides of the canal all the way down to the second lock, and beyond. There was also some green growth in the pound.

Samples drawn.	Approximate dilution of effluent with canal water.		Canal water just above outfall.	Sewage effluent	Canal water 100 yards below outfall.	Canal water 500 yards below outfall.	Canal water 1,000 yards below outfall.	Canal water 1,500 yards below outfall.
April 19, 1909.	4 to 1	Ammoniacal nitrogen	0·005	2·72	—	0·576	0·452	0·185
		Albuminoid nitrogen	0·03	0·22	—	0·07	0·06	0·04
		Nitric nitrogen	0·21	0·00	—	0·17	0·14	0·20
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·22	1·01	—	0·32	0·35	0·22
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·72	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·33	4·65	—	0·60	0·52	0·33
		Chlorine	1·66	4·48	—	2·56	2·45	1·88
		Suspended solids	—	3·33	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·98	0·08	—	0·27	0·34	0·82
Aug. 9, 1909.	4 to 1	Ammoniacal nitrogen	0·005	1·500	0·163	0·274	—	—
		Albuminoid nitrogen	0·07	0·21	0·09	0·10	—	—
		Nitric nitrogen	0·07	0·40	0·15	0·15	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·33	0·63	0·36	0·44	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·94	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·68	2·67	0·46	0·32	—	—
		Chlorine	1·43	4·40	1·75	2·12	—	—
		Suspended solids	3·2	2·1	2·7	4·6	—	—
		Oxygen in solution when drawn	0·92	0·06	0·73	0·56	0·52	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·89	0·00	0·62	0·44	—	—
Nov. 11, 1909.	4 to 1	Ammoniacal nitrogen	0·007	0·64	—	—	—	0·172
		Albuminoid nitrogen	0·06	0·14	—	—	—	0·05
		Nitric nitrogen	0·32	0·40	—	—	—	0·36
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·39	0·25	—	—	—	0·37
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·51	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·46	2·40	—	—	—	0·47
		Chlorine	1·72	4·32	—	—	—	1·93
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·02	0·24	—	—	—	0·82

Samples drawn.	Approximate dilution of effluent with canal water.		Canal water just above outfall.	Sewage effluent	Canal water 100 yards below outfall.	Canal water 500 yards below outfall.	Canal water 1,000 yards below outfall.	Canal water 1,500 yards below outfall.
Jan. 14, 1910.	4 to 1	Ammoniacal nitrogen	—	—	—	—	—	—
		Albuminoid nitrogen	—	—	—	—	—	—
		Nitric nitrogen	—	—	—	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	—	—	—	—	—	—
		Chlorine	—	—	—	—	—	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	0·99	0·20	0·78	—	0·75	—
		Oxygen in solution when analysed, *i.e.*, after days	—	—	—	—	—	—
June 22, 1910.	4 to 1	Ammoniacal nitrogen	0·027	1·460	0·036	—	—	—
		Albuminoid nitrogen	0·03	0·17	0·03	—	—	—
		Nitric nitrogen	0·13	0·00	0·19	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·22	0·86	0·19	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·86	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·19	2·41	0·45	—	—	—
		Chlorine	1·36	3·70	1·57	—	—	—
		Suspended solids	1·2	1·9	0·7	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·95	0·08	0·82	—	—	—
Feb. 17, 1911.	4 to 1	Ammoniacal nitrogen	0·007	0·652	0·077	—	—	—
		Albuminoid nitrogen	0·02	0·10	0·03	—	—	—
		Nitric nitrogen	0·45	0·09	0·38	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·17	0·38	0·16	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·07	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·14	0·93	0·23	—	—	—
		Chlorine	1·35	2·97	1·63	—	—	—
		Suspended solids	3·4	0·9	1·7	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·08	0·12	0·86	—	—	—
June 7, 1911.	4 to 1	Ammoniacal nitrogen	0·014	0·180	0·062	0·172	0·106	0·079
		Albuminoid nitrogen	0·02	0·07	0·03	0·05	0·04	0·03
		Nitric nitrogen	0·21	0·58	0·21	0·17	0·22	0·21
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·12	0·21	0·07	0·22	0·19	0·19
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·35	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·17	0·30	0·18	0·16	0·17	0·19
		Chlorine	1·40	3·17	1·71	2·09	1·79	1·82
		Suspended solids	0·7	0·8	0·9	0·7	0·6	0·8
		Oxygen in solution when drawn	0·92	0·15	0·89	0·75	0·73	0·98
		Oxygen in solution when analysed, *i.e.*, after 5 days	0·82	0·10	0·68	0·39	0·59	0·76

Summary.—1. This effluent, when diluted with about four times its own volume of fairly clean water, moving in an excessively sluggish current, did not give rise to smell.

2. The water was on occasion materially deoxygenated in warm weather through admixture with the effluent.

3. No offensive deposit of mud was produced in the canal as the result of the discharge of about 3·0 parts of suspended matter. Passing boats, and especially steam boats, have the effect of stirring up mud, however.

4. Much grey fungus was present in the water below the outfall. This growth extended for about half a mile.

5. Only fish of the minnow type have been observed in the canal pound which receives the effluent.

BUXTON AND THE RIVER WYE.

Population.—10,000.
Sewerage System.—Partially separate
Dry weather Flow.—1,000,000 gallons per 24 hours.
Nature of Sewage.—Weak domestic.
Treatment.—Precipitation, settlement and straining beds followed by percolating filters. A good deal of surface water from the roads is discharged direct into the river, and some tank liquor is also discharged in times of storm.

Total capacity of precipitation tanks	770,000 gallons.
Total cubic content of Filters:—	
Straining beds	1,666½ yards.
Percolating filters	5,320 „
Total	6,986½ yards.

Effluent.—This is a clear and highly oxidised effluent, with a slight brown tinge. It has a clean earthy smell and does not froth on shaking. The suspended solids average about 2 parts.

	Parts per 100,000.
Ammoniacal nitrogen	0·13
Nitric nitrogen	1·28
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	0·70
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	0·26
In 5 days	0·78

Name of Stream.—The Wye, a tributary of the Derwent.

Velocity.—The current velocity, measured over a distance of 5,000 yards in fairly dry weather, was found to be about 100 feet per minute. The current is thus very rapid.

Width of stream—30 to 40 feet. In fairly dry weather the depth of the stream varies from a few inches to 3 or 4 feet.

The river is much swollen in times of storm and may be very low in long continued dry weather.

The dilution of the effluent in fairly dry weather is about 2·5 to 1 at the outfall, but the river receives large accessions of water from the limestone immediately below the outfall.

Effect of Effluent Discharge.—Visits paid in January, July (two) and October, 1909, May, 1910, February, May (two), June and July, 1911.

Considerable quantities of fungus at effluent outfall, and extending for about 100 yards. A fair quantity of loose brown deposit on stones, and a great wealth of green weed, especially *Ranunculus aquatilis*, which carpets the bed of the river for many miles.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 1,500 yards below outfall.	River water 3,600 yards below outfall.	River water 7,700 yards below outfall.
Jan. 25, 1909.	5 to 1	Ammoniacal nitrogen	0·007	0·022	—	0·010	—	0·002
		Albuminoid nitrogen	0·01	0·03	—	0·01	—	0·01
		Nitric nitrogen	0·16	0·74	—	0·20	—	0·17
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·08	0·16	—	0·05	—	0·03
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·34	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·12	0·43	—	·10	—	0·08
		Chlorine	1·05	2·15	—	1·06	—	0·86
		Suspended solids	2·8	2·7	—	2·2	—	1·4
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	1·18	0·98	—	1·14	—	1·15
July 23, 1909.	2½ to 1	Ammoniacal nitrogen	0·021	0·011	0·063	0·050	0·005	0·005
		Albuminoid nitrogen	0·02	0·03	0·02	0·02	0·01	0·01
		Nitric nitrogen	0·11	1·15	0·25	0·20	0·25	0·24
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·11	0·26	0·24	0·18	0·10	0·11
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·36	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·07	0·09	0·13	0·15	0·05	0·08
		Chlorine	1·23	3·07	1·61	1·35	1·01	0·98
		Suspended solids	—	1·6	1·5	—	—	—
		Oxygen in solution when drawn	0·86	0·74	0·79	0·84	0·84	0·86
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·80	0·80	0·72	0·77	1·02	1·08
Oct. 14, 1909	3 to 1	Ammoniacal nitrogen	0·006	0·020	—	0·016	0·006	0·005
		Albuminoid nitrogen	0·01	0·05	—	0·01	0·01	0·01
		Nitric nitrogen	0·13	1·0	—	0·21	0·20	0·18
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·24	0·28	—	0·16	0·16	0·16
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·49	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·12	0·30	—	0·16	0·12	0·15
		Chlorine	0·77	2·62	—	1·00	1·00	0·09
		Suspended solids	—	1·11	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·04	0·88	—	0·96	1·04	1·07

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 1,500 yards below outfall.	River water 3,600 yards below outfall.	River water 7,700 yards below outfall.
ay 5, 1910	20 to 1	Ammoniacal nitrogen	0·074	0·010	0·074	—	0·068	—
		Albuminoid nitrogen	0·06	0·06	0·08	—	0·06	—
		Nitric nitrogen	0·11	2·41	0·05	—	0·11	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·84	0·36	0·82	—	0·67	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·51	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·74	0·37	0·93	—	0·76	—
		Chlorine	1·04	2·48	0·92	—	0·90	—
		Suspended solids	24·20	2·20	21·00	—	17·00	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	0·78	0·89	0·72	—	0·85	—
eb. 10, 1911.	2½ to 1	Ammoniacal nitrogen	0·018	0·580	0·014	—	—	—
		Albuminoid nitrogen	0·01	0·25	0·01	—	—	—
		Nitric nitrogen	0·12	0·63	0·22	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·08	1·33	0·04	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·38	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·24	3·02	0·17	—	—	—
		Chlorine	1·15	3·73	0·98	—	—	—
		Suspended solids	1·50	7·50	1·10	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·21	0·12	0·83	—	—	—
ay 4, 1911.	3 to 1	Ammoniacal nitrogen	0·032	0·032	0·025	—	0·018	0·015
		Albuminoid nitrogen	0·03	0·07	0·02	—	0·02	0·02
		Nitric nitrogen	0·14	1·30	0·13	—	0·18	0·20
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	0·25	0·21	—	0·17	0·16
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·60	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·40	0·67	0·37	—	0·35	0·16
		Chlorine	1·02	2·48	0·96	—	0·91	0·98
		Suspended solids	2·3	2·5	1·9	—	3·1	2·2
		Oxygen in solution when drawn	1·00	0·88	0·98	—	0·99	1·01
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·94	0·82	0·99	—	1·14	1·06
ay 24, 1911.	2½ to 1	Ammoniacal nitrogen	0·005	0·360	—	0·027	—	—
		Albuminoid nitrogen	0·01	0·11	—	0·02	—	—
		Nitric nitrogen	0·14	1·11	—	0·27	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·06	0·59	—	0·09	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·19	1·71	—	0·28	—	—
		Chlorine	1·42	3·80	—	1·44	—	—
		Suspended solids	1·0	3·1	—	0·8	—	—
		Oxygen in solution when drawn	—	—	—	0·89	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·96	0·25	—	0·75	—	—
uly 6, 1911.	3½ to 1	Ammoniacal nitrogen	0·294	0·390	0·142	0·016	0·004	—
		Albuminoid nitrogen	0·03	0·09	0·03	0·06	0·02	—
		Nitric nitrogen	0·03	0·78	0·19	0·31	0·24	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·20	0·76	0·17	0·09	0·10	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·74	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·44	2·00	0·50	0·32	0·13	—
		Chlorine	1·75	4·00	1·63	1·54	1·44	—
		Suspended solids	2·4	7·4	2·5	1·9	1·8	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	0·13	0·12	0·55	0·54	0·87	—

Summary.—1. This effluent, diluted with about 2·5 (and more) times its own volume of clean water moving in a rapid current, gave rise to no nuisance from smell.

2. The water was not materially deoxygenated through admixture with the effluent.

3. No offensive deposit of mud was caused by the discharge of about 2·0 parts of suspended matter in the effluent.

4. Grey growth was present in considerable quantities for a short distance below the outfall.

A green water-weed (*Ranunculus aquatilis*) grew in great abundance from about half a mile below the outfall and extended for many miles.

5. No fish were observed for two miles below the outfall.

CAMBRIDGE AND THE RIVER CAM.

Population.—55,000.
Sewerage System.—Partially separate.
Dry weather Flow.—2,200,000 gallons per 24 hours.
Nature of Sewage.—Rather weak domestic sewage, containing brewery refuse.
Treatment.—Settlement and land filtration.

Total tank capacity - - -	424,000 gallons.
Total irrigable area of land - -	about 80 acres.

Effluent.—This is an opalescent liquid with a brownish tint. As a rule, it has a clean earthy smell, but three samples out of eight had an unpleasant smell. It contains on the average about 2·6 parts of suspended matter.

One sample out of eight putrified upon incubation.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	1·23
Nitric nitrogen - - - - - - -	0·91
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	1·12
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours - - - - - - -	0·70
In 5 days - - - - - - - -	1·25

Name of Stream.—The Cam.

Velocity.—The current velocity as measured in dry weather over a length of 800 yards was found to be about 16 feet per minute. The flow is thus sluggish.

The river is about 80 feet wide and averages 4 to 6 feet deep. The rise in times of storm is gradual, the flood water coming mainly from the cultivated land and also from the borough of Cambridge.

The dry weather flow of the river is about 26,000,000 gallons: hence the dilution of the effluent is about 12 to 1.

Effect of Effluent Discharge.—Visits paid in January and June, 1909, and June and August, 1910. The mixing of the effluent with the river water is not complete until about a quarter of a mile below the outfall. A small quantity of grey growth could usually be seen for a distance of about 100 yards, below the outfall, on the outfall side of the river. The water at this side of the river was rendered rather turbid for a somewhat longer distance and the reeds and rushes were also fouled with floating matter.

Beyond these effects little change could be observed as the result of the effluent discharge.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 400 yards below outfall.	River water 800 yards below outfall.	Rive wate 1,50 yards belo outfa
Jan. 20, 1909.	12 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·019	0·124	0·068	—	0·114	0·1
		Albuminoid nitrogen - - - - - - - - - -	0·01	0·14	0·02	—	0·03	0·0
		Nitric nitrogen - - - - - - - - - - -	0·44	0·40	0·45	—	0·40	0·4
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·14	1·09	0·19	—	0·19	0·2
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·61	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·18	1·55	0·23	—	0·26	0·5
		Chlorine - - - - - - - - - - - -	2·15	8·20	2·38	—	2·60	2·5
		Suspended solids - - - - - - - - -	—	2·6	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	1·12	0·05	1·05	—	0·85	0·9
June 23, 1909.	12 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·152	1·910	0·148	—	0·214	0·1
		Albuminoid nitrogen - - - - - - - - - -	0·06	0·19	0·07	—	0·05	0·0
		Nitric nitrogen - - - - - - - - - - -	0·27	0·12	0·30	—	0·30	0·3
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·33	0·81	0·31	—	0·33	0·2
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·10	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	—	0·85	0·45	—	0·46	0·3
		Chlorine - - - - - - - - - - - -	2·58	9·49	2·57	—	2·84	2·7
		Suspended solids - - - - - - - - -	—	3·1	—	—	0·6	—
		Oxygen in solution when drawn - - - - - - -	0·47	0·09	0·56	—	0·66	0·6
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·37	0·05	0·61	—	0·55	0·6
June 23, 1910.	12 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·012	0·890	0·025	—	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·02	0·07	0·03	—	—	—
		Nitric nitrogen - - - - - - - - - - -	0·06	0·09	0·20	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·23	0·42	0·24	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·82	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·20	0·34	0·31	—	—	—
		Chlorine - - - - - - - - - - - -	1·92	5·39	2·30	—	—	—
		Suspended solids - - - - - - - - -	0·9	1·8	0·6	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·8	0·35	0·66	—	—	—

Samples drawn.	Approximate dilution of effluents with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 400 yards below outfall.	River water 800 yards below outfall.	River water 1,000 yards below outfall.
ugust 12,1910.	12 to 1	Ammoniacal nitrogen	0·009	0·640	—	0·045	0·044	—
		Albuminoid nitrogen	0·02	0·09	—	0·02	0·02	—
		Nitric nitrogen	0·30	2·31	—	0·45	0·41	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·13	0·41	—	0·16	0·17	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·70	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·15	1·20	—	0·27	0·27	—
		Chlorine	1·85	8·09	—	2·57	2·46	—
		Suspended solids	0·16	1·40	—	0·20	0·70	—
		Oxygen in solution when drawn	0·87	0·13	—	0·73	0·73	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·89	0·24	—	0·80	0·80	—

Summary.—1. This effluent, when diluted with about 12 times its own volume of fairly clean water moving in a sluggish current, did not give rise to nuisance from smell.

2. The water was not materially deoxygenated through admixture with the effluent. The dissolved oxygen contents of the water above the outfall is liable to be low.

3. There was a comparatively small deposit of black mud immediately below the effluent outfall.

4. Grey fungus was present in moderate quantity for a short distance below the outfall.

5. Coarse fish were abundant below the outfall.

CHELMSFORD AND THE RIVER CHELMER.

Population.—16,000.
Sewerage System—Mainly combined.
Dry weather Flow.—500,000 gallons per 24 hours.
Nature of Sewage.—Strong domestic sewage containing brewery and tannery refuse.
Treatment.—Settling tanks followed by land irrigation and filtration. The soil is rather stiff.

Total tank capacity	137,000 gallons.
Total irrigable area	77·619 acres.

Effluent.—This was an opalescent liquid with a brownish tint, and it contained, on the average, about 2·5 parts of suspended matter per 100,000. It had sometimes a clean and sometimes an unpleasant smell. One sample out of six putrified upon incubation.

	Parts per 100,000.
Ammoniacal nitrogen	1·21
Nitric ,,	0·24
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·34
Dissolved oxygen taken up from water at 65° F.	
In 48 hours	0·49
In 5 days	1·22

Two samples of land effluent, drawn in stormy weather, were examined in November and December, 1909. The first of these was putrescent on incubation and took up 4·4 parts of dissolved oxygen in 5 days. The second was non-putrescent and took up 2·8 parts. They contained 14 to 16 parts of suspended solids, of which two-thirds were mineral matter.

Name of Stream.—Chelmer.

Velocity.—The mean current velocity, as measured in dry weather over a distance of 1,400 yards below the outfall, was about 16 feet per minute. The flow is thus sluggish.

The river is about 40 to 50 feet wide and 3 to 5 feet deep. Its rise in times of storm is gradual, the flood water being derived mainly from cultivated land. The dry weather flow of the river is 13,000,000 gallons, hence the dilution of the effluent is about 26 to 1.

Effect of Effluent Discharge.—Visits were paid in February, September and November, 1909, June, August and October, 1910, and January, May, June and July, 1911. The effluent is discharged into a very sluggish reach of river between two locks. It altered the appearance of the river very considerably; the water was rendered turbid and of a dark colour; grey fungus was present for about a mile, and minute life was abundant.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 1,400 yards below outfall.	River water 1,800 yards below outfall.
Feb. 1, 1909.	26 to 1	Ammoniacal nitrogen	0·025	1·510	0·161	0·101	0·212
		Albuminoid nitrogen	0·02	0·13	0·03	0·03	0·04
		Nitric nitrogen	0·36	0·00	0·37	0·36	0·34
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·20	1·04	0·26	0·26	0·30
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·41	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·19	2·06	0·30	0·35	0·39
		Chlorine	3·54	11·68	4·05	4·16	4·39
		Suspended solids	—	3·4	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·21	0·00	1·07	1·04	0·97
Sept. 23, 1909.	26 to 1	Ammoniacal nitrogen	0·010	1·700	0·192	0·272	0·132
		Albuminoid nitrogen	0·02	0·31	0·06	0·07	0·05
		Nitric nitrogen	0·10	0·00	0·26	0·17	0·17
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·30	1·34	0·46	0·50	0·40
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·27	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·13	2·12	0·36	0·51	0·33
		Chlorine	3·40	13·80	4·63	4·90	4·47
		Suspended solids	—	5·0	1·0	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·86	0·02	0·46	0·13	0·39
Nov. 8, 1909.	52 to 1	Ammoniacal nitrogen	0·022	2·22	—	—	0·067
		Albuminoid nitrogen	0·04	0·41	—	—	0·03
		Nitric nitrogen	0·23	0·00	—	—	0·27
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·42	1·39	—	—	0·36
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·77	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·41	4·53	—	—	0·24
		Chlorine	3·22	12·35	—	—	3·35
		Suspended solids	—	6·5	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·06	0·06	—	—	1·04

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 1,400 yards below outfall.	River water 1,800 yards below outfall.
June 21, 1910.	26 to 1	Ammoniacal nitrogen	0·003	2·110	—	0·083	—
		Albuminoid nitrogen	0·04	0·34	—	0·07	—
		Nitric nitrogen	0·15	0·00	—	0·16	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·29	1·68	—	0·36	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·67	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·23	2·72	—	0·42	—
		Chlorine	3·23	14·10	—	3·45	—
		Suspended solids	1·0	5·2	—	1·0	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·83	0·03	—	0·79	—
Aug. 11, 1910.	26 to 1	Ammoniacal nitrogen	0·020	2·04	0·314	0·099	—
		Albuminoid nitrogen	0·03	0·27	0·07	0·04	—
		Nitric nitrogen	0·10	0·04	0·09	0·07	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·26	1·43	0·39	0·30	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·77	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·14	2·58	—	0·30	—
		Chlorine	3·33	14·70	5·01	3·92	—
		Suspended solids	0·55	4·90	0·95	0·95	—
		Oxygen in solution when drawn	0·76	0·05	0·44	0·53	0·57
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·69	0·00	0·23	0·49	—
Oct. 4, 1910.	26 to 1	Ammoniacal nitrogen	0·013	1·660	0·158	0·241	0·116
		Albuminoid nitrogen	0·02	0·17	0·04	0·05	0·03
		Nitric nitrogen	0·17	0·68	0·21	0·32	0·25
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	1·17	0·30	0·33	0·26
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·97	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·14	2·60	0·25	0·35	0·22
		Chlorine	3·19	13·88	4·15	4·40	3·95
		Suspended solids	—	4·1	—	—	—
		Oxygen in solution when drawn	0·90	0·00	0·72	0·31	0·55
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·89	0·03	0·65	0·15	0·61
Jan. 16, 1911.	26 to 1	Ammoniacal nitrogen	0·022	1·69	0·172	—	—
		Albuminoid nitrogen	0·02	0·19	0·05	—	—
		Nitric nitrogen	0·33	0·25	0·32	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·30	2·05	0·39	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·60	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·26	4·1	0·54	—	—
		Chlorine	2·80	—	3·71	—	—
		Suspended solids	1·2	5·5	2·3	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·19	0·04	1·08	—	—
May 3, 1911.	26 to 1	Ammoniacal nitrogen	0·003	1·850	0·083	0·105	0·107
		Albuminoid nitrogen	0·03	0·20	0·04	0·04	0·04
		Nitric nitrogen	0·15	0·24	0·19	0·25	0·27
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	1·34	0·31	0·32	0·35
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·25	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·47	2·42	0·47	0·45	0·51
		Chlorine	3·35	12·70	3·83	4·07	4·25
		Suspended solids	1·6	6·9	1·2	1·8	1·9
		Oxygen in solution when drawn	1·04	0·15	1·02	0·97	0·96
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·11	0·07	0·97	0·89	0·87
June 16, 1911.	26 to 1	Ammoniacal nitrogen	0·014	1·640	0·096	0·066	0·024
		Albuminoid nitrogen	0·04	0·24	0·03	0·03	0·04
		Nitric nitrogen	0·10	0·00	0·08	0·12	0·18
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·21	1·01	0·28	0·33	0·27
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·87	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·15	3·35	0·30	0·25	0·25
		Chlorine	3·11	13·30	4·15	3·55	4·00
		Suspended solids	1·0	4·2	0·9	0·7	1·2
		Oxygen in solution when drawn	0·94	0·07	0·76	0·50	0·75
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·78	0·12	0·65	0·42	0·72

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 30 yards below outfall.	River water 1,400 yards below outfall.	River water 1,800 yards below outfall.
July 4, 1911.	26 to 1	Ammoniacal nitrogen - - - - - - - - -	0·010	1·540	0·093	0·097	0·02
		Albuminoid nitrogen - - - - - - - - -	0·03	0·23	0·03	0·04	0·04
		Nitric nitrogen - - - - - - - - - - -	0·11	0·42	0·12	0·17	0·20
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·25	1·13	0·33	0·37	0·39
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·15	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·16	4·00	0·27	0·46	0·14
		Chlorine - - - - - - - - - - - - -	3·4	13·82	3·97	4·13	4·00
		Suspended solids - - - - - - - - -	1·7	5·3	1·1	1·1	2·7
		Oxygen in solution when drawn - - - - - - -	0·82	0·15	0·69	0·39	0·63
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·75	0·11	0·73	0·41	0·62

Summary.—1. This effluent, when diluted with about 26 times its own volume of moderately clean water moving in a sluggish current, did not give rise to smell.

2. The water was materially deoxygenated through admixture with the effluent.

3. No deposit of offensive mud has been observed. There were about 2·5 parts of suspended matter in the effluent.

4. A considerable quantity of grey fungus was present in the water below the outfall; it extended for nearly a mile. Green algal growth was, in summer, plentiful below the outfall. The water swarmed with water insects and minute life.

5. Coarse fish were present below the outfall.

CONSETT (DURHAM) AND THE RIVER DERWENT.

Population.—9,000.
Sewerage System.—Combined.
Dry weather Flow.—180,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—Irrigation over and filtration through land.

Effluent.—A slightly opalescent liquid with a brownish tinge, and containing about 2 parts of suspended solids. As a rule, it had a clean earthy smell.

	Parts per 100,000.
Ammoniacal nitrogen	0·60
Nitric nitrogen	0·36
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	0·83
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	0·31
In 5 days	0·93

Name of Stream.—The Derwent.

Velocity.—The mean current velocity, as measured in fairly dry weather, over a stretch of half a mile immediately below the sewage works, was about 60 feet per minute. The current is thus a rapid one.

The river varies from about 60 to 100 feet in width. Generally speaking, it is shallow but with occasional deep pools. The bed of the river is rock and boulders.

The flow in dry weather is about 15 million gallons, which makes the dilution of the effluent something like 80 to 1. The river rises rapidly in times of storm.

The water of the river is clear and bright.

Effect of the Effluent Discharge.—Visits were paid in August, 1908, May and July, 1909, and May, 1912.

The outfall is at the side of the river in a shallow stoney reach.

Grey algal growth was plentiful for a distance of about 100 yards below the outfall, on the outfall side of the river. In dry weather it could be traced for about 300 yards. Green algal growth also made its appearance in moderate quantity below the outfall.

There was a deposit of mud against the outfall.

These were the only sensible signs of pollution in dry weather.

In wet weather the bed of the Derwent is very much fouled with matter brought down by a rivulet which receives not merely the storm sewage from Consett, but also drainage from very large waste heaps at the iron works

This rivulet joins the Derwent about half a mile below the effluent outfall.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall	River water 400 yards below outfall.	River water 1,200 yards below outfall.	River water 2,700 yards below. outfall.
July 1, 1909.	80 to 1	Ammoniacal nitrogen	0·001	0·220	0·028	0·005	0·005	—
		Albuminoid nitrogen	0·01	0·07	0·02	0·01	0·01	—
		Nitric nitrogen	0·01	0·63	0·15	0·03	0·06	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·12	—	0·21	0·18	0·20	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·54	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·05	0·70	0·13	0·10	0·14	—
		Chlorine	1·06	4·23	1·43	1·03	1·09	—
		Suspended solids	—	3·70	—	—	—	—
		Oxygen in solution when drawn	0·96	0·69	0·97	0·97	0·97	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·17	0·82	1·01	1·05	1·02	—
May 7, 1912.	80 to 1	Ammoniacal nitrogen	0·001	0·230	0·025	0·004	0·034	0·014
		Albuminoid nitrogen	0·01	0·10	0·01	0·01	0·02	0·02
		Nitric nitrogen	0·03	0·30	0·05	0·03	0·02	0·07
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·07	0·44	0·11	0·07	0·11	0·13
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·63	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·05	0·55	0·08	0·05	0·15	0·21
		Chlorine	—	—	—	—	—	—
		Suspended solids	—	2·1	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·94	0·73	0·92	0·99	0·93	0·91

Summary.—1. This effluent, when diluted with about 80 times its own volume of very clean water moving in a rapid current, did not give rise to smell.

2. The river water was not materially deoxygenated through admixture with the effluent.

3. There was a small deposit of mud among the stones against the effluent outfall, but otherwise the river bed was clear as far as the storm sewage outfall. Below the latter outfall the river bed was occasionally much fouled with solid matter.

4. Grey algal growth was plentiful for about 100 yards below the outfall on one side of the river. It could be seen in the water for about 300 yards but no farther in dry weather.

5. There were trout and other fish in the river immediately below the outfall.

COVENTRY AND THE RIVER AVON.

Population.—90,000.

Sewerage System.—Combined (chiefly) and partially separate.

Dry weather Flow.—3,000,000 gallons per 24 hours at commencement of observations in 1909, 4,000,000 gallons per 24 hours in 1911.

Nature of Sewage.—Domestic with trades waste.

Treatment.—Settlement followed by land irrigation and land filtration.

Storm sewage is streamed and settled over land. This latter liquid is discharged into the River Sowe, a tributary of the Avon, which joins the main river two or three miles below the Coventry sewage farm.

Total tank capacity - - - - - - - - - - 521,000 gallons.

Total irrigable area of land at time observations were made - 378 acres.

Note.—This area has been largely extended since these observations were made, a point specially to be borne in mind in considering the facts here recorded.

Effluent.—The effluents from the northern and southern outfalls (about one mile apart) were of very variable quality during our observations, the variability being due to the limited area of land available at the time. The following figures do not, therefore, accurately represent the average discharge into the Avon.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	2·14
Nitric nitrogen - - - - - - -	1·11
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - - - -	1·15
Oxygen taken up from water at 65° F.:	
In 48 hours - - - - - - - -	0·46
In 5 days - - - - - - - -	0·89
Suspended solids - - - - - - -	2·60

Name of Stream.—The River Avon.

Velocity.—A mile and a quarter below the lower Coventry outfall the river is dammed by means of a weir. This affects the depth of the river almost as far back as the lower outfall rendering the current very sluggish. The current velocity in this reach, as measured in dry weather varied from 5 to 12 feet per minute.

Below the two outfalls the river varies from about 20 to 50 feet in width. Close to the weir it is over 100 feet wide. The depth varies from about 2 to 15 or even 20 feet.

The dry weather flow is about 7,500,000 gallons per 24 hours, but the volume of water in the river is subject to wide variation owing to mills and weirs.

Since the flow of effluent in dry weather is about 2,500,000 gallons per 24 hours the dilution given by the river water is only about 3 to 1.

The bed of the river is muddy and much overgrown with weeds, flags and rushes.

Effect of Effluent Discharge.—Visits were paid in May and August, 1909, April and September, 1910, January, April, May, June and July, 1911,

The admixture of the variable effluents considerably altered the appearance of the river as far as and below Stoneleigh Abbey.

Grey algal growth (*cladothrix dichotoma*) was abundant below both outfalls and it extended for a distance of nearly two miles below the upper outfall.

In the deep and very sluggish reach about half a mile below the lower outfall the water in dry weather was very dark in appearance, and at certain seasons of the year it supported innumerable aquatic insects of various kinds and great quantities of green algæ.

In parts of this very sluggish reach there were large deposits of putrifying mud.

A good many dead fish were seen in the reach during warm dry weather, and at such times there was usually an objectionable smell from the river water.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent.		River water 400 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	Riv wat 2,50 yarc belo outfa
				North outfall.	South outfall.				
May 13, 1909.	3 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·017	1·930	—	1·081	0·743	0·696	—
		Albuminoid nitrogen - - - - - - - - - -	0·03	0·10	—	0·11	0·09	0·08	—
		Nitric nitrogen - - - - - - - - - - -	0·16	1·08	—	0·38	0·25	0·29	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·17	0·62	—	0·57	0·52	0·54	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·02	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·20	1·0	—	1·0	0·80	0·75	—
		Chlorine - - - - - - - - - - - - -	6·51	10·84	—	6·40	5·11	5·07	—
		Suspended solids - - - - - - - - - -	0·56	1·5	—	2·0	2·3	2·4	—
		Oxygen in solution when drawn - - - - - -	—	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	0·93	0·51	—	0·37	0·20	0·10	—
Aug. 21, 1909.	6 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·009	1·820	—	—	0·949	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·03	0·13	—	—	0·07	—	—
		Nitric nitrogen - - - - - - - - - - -	0·13	1·17	—	—	0·23	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·35	0·79	—	—	0·52	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·24	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·29	1·24	—	—	0·34	—	—
		Chlorine - - - - - - - - - - - - -	3·72	10·80	—	—	5·17	—	—
		Suspended solids - - - - - - - - - -	—	1·3	—	—	—	—	—
		Oxygen in solution when drawn - - - - - -	0·66	0·56	—	—	0·32	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	0·64	0·56	—	—	0·46	—	—

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent.		River water 400 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	River water 2,500 yards below outfall.
				North outfall.	South outfall				
pril 26, 1910.	3 to 1	Ammoniacal nitrogen	0·004	1·970	—	0·182	0·378	—	—
		Albuminoid nitrogen	0·04	0·18	—	0·03	0·06	—	—
		Nitric nitrogen	0·19	0·71	—	0·31	0·26	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	—	—	0·40	0·37	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·71	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·10	0·75	—	0·38	0·43	—	—
		Chlorine	5·02	10·86	—	4·80	3·90	—	—
		Suspended solids	—	1·9	—	—	—	—	—
		Oxygen in solution when drawn	1·50	0·83	—	0·94	0·77	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·15	0·76	—	0·89	0·77	—	—
ept. 28 1910.	3 to 1	Ammoniacal nitrogen	0·006	—	—	—	1·176	1·115	—
		Albuminoid nitrogen	0·02	—	—	—	0·07	0·07	—
		Nitric nitrogen	0·32	—	—	—	0·04	0·14	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·23	—	—	—	0·59	0·54	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·17	—	—	—	0·55	0·40	—
		Chlorine	5·19	—	—	—	8·84	8·18	—
		Suspended solids	—	—	—	—	—	—	—
		Oxygen in solution when drawn	0·72	—	—	—	0·07	0·10	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·81	—	—	—	0·15	0·25	—
an. 24, 1911,	10 to 1	Ammoniacal nitrogen	0·029	1·520	1·580	—	0·428	0·409	0·461
		Albuminoid nitrogen	0·02	0·13	0·10	—	0·08	0·05	0·05
		Nitric nitrogen	0·24	1·54	1·35	—	0·33	0·37	0·38
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·24	0·42	0·58	—	0·15	0·43	0·41
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·07	1·07	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·19	1·22	0·50	—	—	—	—
		Chlorine	2·28	9·97	9·27	—	3·35	3·28	3·28
		Suspended solids	0·6	1·8	1·0	—	2·2	1·0	1·5
		Oxygen in solution when drawn	—	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·12	0·73	0·61	—	0·62	0·64	0·90
pril 5, 1911.	3 to 1	Ammoniacal nitrogen	0·006	1·670	1·590	—	0·201	0·365	0·435
		Albuminoid nitrogen	0·02	0·18	0·11	—	0·05	0·05	0·07
		Nitric nitrogen	0·19	1·14	1·34	—	0·18	0·36	0·31
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	0·63	0·80	—	0·32	0·38	0·44
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·03	1·23	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·06	0·72	0·99	—	0·68	0·69	1·02
		Chlorine	2·67	11·40	10·70	—	3·87	3·90	4·31
		Suspended solids	1·3	1·8	2·3	—	1·1	1·1	1·3
		Oxygen in solution when drawn	—	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·18	0·84	0·81	—	1·00	0·80	0·72
pril 19, 1911.	3 to 1	Ammoniacal nitrogen	0·007	1·840	1·720	—	0·308	0·467	0·534
		Albuminoid nitrogen	0·04	0·15	0·17	—	0·08	0·08	0·08
		Nitric nitrogen	0·29	1·66	0·90	—	0·37	0·31	0·38
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·25	0·56	0·69	—	0·33	0·39	0·40
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·77	1·08	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·30	1·06	0·97	—	0·50	0·78	0·75
		Chlorine	3·00	10·76	10·50	—	4·30	4·86	4·92
		Suspended solids	1·2	1·7	2·8	—	1·8	1·8	1·8
		Oxygen in solution when drawn	—	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·23	0·80	0·72	—	0·77	0·39	0·47
pril 27, 1911.	3 to 1	Ammoniacal nitrogen	0·010	2·340	1·790	—	0·694	0·576	0·496
		Albuminoid nitrogen	0·04	0·24	0·22	—	0·09	0·16	0·08
		Nitric nitrogen	0·21	0·97	0·90	—	0·36	0·34	0·36
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	1·03	1·06	—	0·54	0·55	0·44
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·80	1·62	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·44	1·65	1·66	—	1·12	1·29	1·17
		Chlorine	4·38	10·90	10·76	—	6·26	5·72	5·47
		Suspended solids	1·3	3·48	2·5	—	2·1	1·9	1·9
		Oxygen in solution when drawn	1·42	0·60	0·80	—	0·48	0·44	0·72
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·18	0·4	0·73	—	0·17	0·21	0·51

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent.		River water 400 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	Rive wate 2,50 yard belo outfal
				North outfall.	South outfall.				
May 23, 1911.	3 to 1	Ammoniacal nitrogen - - - - - - - - -	0·007	—	—	—	—	0·416	—
		Albuminoid nitrogen - - - - - - - - -	0·04	—	—	—	—	0·04	—
		Nitric nitrogen - - - - - - - - - -	0·19	—	—	—	—	0·38	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·32	—	—	—	—	0·46	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·39	—	—	—	—	0·53	—
		Chlorine - - - - - - - - - - - -	6·1	—	—	—	—	6·4	—
		Suspended solids - - - - - - - - -	2·2	—	—	—	—	1·7	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	0·97	—	—	—	—	0·39	—

Summary.—1. The Coventry effluent, when diluted with about 3 times its own volume of fairly clean water moving in a sluggish current, gave rise to some smell in warm dry weather.

2. The water of the river was very materially deoxygenated through admixture with the effluent.

3. There were objectionable deposits of mud below the outfall.

4. Grey algal growth was abundant in the river below the outfalls.

5. Coarse fish were usually absent or scarce in the sluggish reach below the outfalls.

HALSTEAD AND THE RIVER COLNE.

Population.—6,500.
Sewerage System.—Mainly combined.
Dry weather Flow.—150,000 gallons per 24 hours.
Nature of Sewage.—Domestic, with brewery and tannery wastes.
Treatment.—Surface irrigation and land filtration of crude sewage.
A new purification plant is in process of construction.
Night sewage and storm sewage are usually sent direct to the river.
Total irrigable area - - - - - - - - 13 acres.
No tanks.

Effluent.—The land effluent discharged throughout the day was of rather unequal quality, owing to the fact that the land was overworked.

The day effluent was a brownish, opalescent liquid with an earthy smell; it contained from 2 to 3 parts of suspended matter per 100,000.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	0·63
Nitric nitrogen - - - - - - -	1·47
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - - - -	0·73
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours - - - - - - -	0·29
In 5 days - - - - - - - -	0·79

The day samples were uniformly non-putrescible on incubation.

Name of Stream.—The river Colne.

Velocity.—The current velocity, as measured over a stretch of 1,600 feet immediately below the outfall in dry weather, was about 13 to 15 feet per minute, that is, it was exceedingly sluggish. The natural current of the river is fairly fast, however, this local slowing up being due to a weir.

The width of the river varies from 20 to 50 feet, and the depth from a few inches to 8 or 9 feet. For a distance of half a mile below the outfall the water has an almost uniform depth of 3 or 4 feet.

The average dry weather flow of the river is about 4,000,000 gallons per 24 hours, which gives a dilution to the effluent and night sewage of about 26 to 1.

Effect of Discharge.—Visits paid in February and June, 1909.

In wet weather all surface water from the streets is carried directly into the river, a mile above the outfall, so that on these occasions there is considerable pollution from surface water alone. The water apparently recovers rapidly from such occasional pollution.

The appearance of the Colne below the Halstead outfall was, at the time of our observations, considerably deteriorated, owing to the discharge into it of unpurified sewage at night and in times of storm.

The water was rendered turbid and opalescent, and there were deposits of putrifying mud for some little distance below the outfall.

Grey algal growth was present in moderate quantity below the outfall.

Samples drawn.	Approximate dilution of effluent by river water.		River water just above outfall	Sewage effluent	River water 150 yards below outfall.	River water 600 yards below outfall.	River water 1,000 yards below outfall.
Feb. 3, 1909.	26 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·021	3·94	0·090	0·082	—
		Albuminoid nitrogen - - - - - - - - - -	0·01	0·60	0·03	0·03	—
		Nitric nitrogen - - - - - - - - - -	0·42	—	0·40	0·37	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·17	5·70	0·22	0·23	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	8·26	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·15	13·72	0·20	0·23	—
		Chlorine - - - - - - - - - - -	3·24	16·23	3·50	3·63	—
		Suspended solids - - - - - - - - -	—	13·7	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 5 days - -	1·05	0·00	1·02	0·99	—
June 24, 1909.	15 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·020	2·69	—	0·179	0·152
		Albuminoid nitrogen - - - - - - - - - -	0·03	0·83	—	0·08	0·08
		Nitric nitrogen - - - - - - - - - -	0·25	0·00	—	0·25	0·16
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·24	4·45	—	0·44	0·46
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	8·84	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·20	16·9	—	0·66	—
		Chlorine - - - - - - - - - - -	3·18	5·41	—	3·42	3·55
		Suspended solids - - - - - - - - -	—	34·7	—	—	—
		Oxygen in solution when drawn - - - - - - -	0·67	0·00	—	0·35	0·36
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·72	0·00	—	0·28	0·20

* This low dilution was due to heavy thunder rain affecting the sewage but not the river flow.

Summary.—As two kinds of liquid were regularly discharged into the river from the Halstead sewage farm (effluent and night sewage) it is difficult to draw any exact inferences.

It is clear, however, that the bed of the river has been at times seriously fouled and the water materially deoxygenated in the sluggish reach below the farm. The fouling would appear to be due mainly to the settlement of sewage suspended matter.

If this inference is correct it might be concluded:—

(1) That the purified effluent does not give rise to nuisance when diluted with about 26 times its own volume of fairly clean water.

(2) That the weak night sewage does give rise to objectionable conditions and smell if discharged into a very sluggish reach, even although the dilution is 26 to 1.

There was a good deal of grey algal growth below the outfall.

HARTLEY WINTNEY AND THE RIVER HART.

Population.—1,600.

Sewerage System.—Partially separate.

Dry weather Flow.—About 60,000 gallons per 24 hours.

Nature of Sewage.—Domestic, with a considerable proportion of brewery refuse.

Treatment.—Septic tank, double contact beds and land.

Total tank capacity - - - - - - - - - -	66,000 gallons.
Total cubic content of contact beds - - - - - -	679 yards.
Total irrigable area of land - - - - - - - -	About 3 acres.

Effluent.—This is derived from a rather strong sewage. It is opalescent and of a brownish tint, with about 3 parts of suspended solids. It is somewhat variable in composition, and occasionally putrescent upon incubation.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	1·17
Nitric „ - - - - - -	0·34
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - - - -	1·65
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours - - - - - - - -	0·76
In 5 days - - - - - - - -	1·39

Name of Stream.—River Hart, a branch tributary of the Thames.

Velocity.—The current is extremely variable (30 to 90 feet per minute in dry weather), sluggish pools alternating with shallow rapids.

The width of the river varies from about 12 to 25 feet, and the depth from a few inches to 6 feet. There are many deep pools, which have a muddy bottom, the shallows being mainly gravel, but generally the bottom is mud. The river does not rise very rapidly in wet weather.

The flow in dry weather is about 4,500,000 gallons per 24 hours, giving a dilution to the effluent of about 75 to 1.

Effect of Effluent Discharge.—Visits paid in February, 1909, and January, May, July and October. 1910. The effluent does not discharge directly into the river, but flows along a ditch about 150 yards long, in which a considerable deposition of solids takes place. There is a good deal of grey growth and black mud in the ditch. As regards the river itself, it may be said that beyond small quantities of grey growth near the outlet end of the ditch, little change could be observed below the outfall.

Samples drawn.	Approximate dilution of effluent by river water.		River water just above outfall.	Sewage effluent	River water 200 yards below outfall.	River water 1,200 yards below outfall.	River water 2,400 yards below outfall.
Feb. 10, 1909.	150 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·012	0·170	0·015	0·017	0·019
		Albuminoid nitrogen - - - - - - - - - -	0·02	0·03	0·01	0·01	0·03
		Nitric nitrogen - - - - - - - - - - -	0·16	0·57	0·16	0·15	0·16
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	0·32	0·18	0·19	0·21
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·27	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·21	0·13	0·18	0·17	0·32
		Chlorine - - - - - - - - - - - - -	1·90	2·88	1·85	1·89	1·94
		Suspended solids - - - - - - - - - -	2·3	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	1·17	0·99	1·22	1·18	1·14
Jan. 12, 1910.	300 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·019	0·31	—	—	0·022
		Albuminoid nitrogen - - - - - - - - - -	0·05	0·07	—	—	0·05
		Nitric nitrogen - - - - - - - - - - -	0·15	0·60	—	—	0·16
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·70	0·44	—	—	0·70
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·80	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·30	0·74	—	—	0·41
		Chlorine - - - - - - - - - - - - -	1·98	3·45	—	—	1·96
		Suspended solids - - - - - - - - - -	4·9	—	—	—	5·7
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	1·06	0·50	—	—	1·02
May 24, 1910.	75 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·011	1·58	0·026	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·02	0·25	0·03	—	—
		Nitric nitrogen - - - - - - - - - - -	0·17	0·00	0·15	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·29	1·55	0·33	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·61	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·18	5·51	0·31	—	—
		Chlorine - - - - - - - - - - - - -	1·80	6·57	1·90	—	—
		Suspended solids - - - - - - - - - -	0·7	4·0	0·7	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	1·05	0·06	0·90	—	—

Samples drawn.	Approximate dilution of effluent by river water.		River water just above outfall.	Sewage effluent	River water 200 yards below outfall.	River water 1,200 yards below outfall.	River water 2,400 yards below outfall.
July 12, 1910.	150 to 1	Ammoniacal nitrogen - - - - - - - - -	0·007	2·020	0·025	0·026	0·018
		Albuminoid nitrogen - - - - - - - - -	0·02	0·15	0·02	0·03	0·03
		Nitric nitrogen - - - - - - - - - -	0·07	0·11	0·11	0·09	0·09
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·35	1·37	0·34	0·30	0·34
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·21	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·10	1·87	0·14	0·04	0·15
		Chlorine - - - - - - - - - - - -	1·72	7·40	1·79	1·86	1·76
		Suspended solids - - - - - - - - -	0·05	2·3	0·9	0·6	0·8
		Oxygen in solution when drawn - - - - - - -	0·77	0·21	0·79	0·74	0·75
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·88	0·09	0·88	0·78	0·78
Oct. 5, 1910.	75 to 1	Ammoniacal nitrogen - - - - - - - - -	0·004	2·180	0·035	0·029	0·021
		Albuminoid nitrogen - - - - - - - - -	0·02	0·23	0·02	0·02	0·02
		Nitric nitrogen - - - - - - - - - -	0·05	0·08	0·06	0·05	0·05
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·20	1·40	0·22	0·23	0·24
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·54	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·08	2·22	0·06	0·07	0·08
		Chlorine - - - - - - - - - - - -	1·78	7·44	1·83	1·89	1·87
		Suspended solids - - - - - - - - -	—	3·4	—	—	—
		Oxygen in solution when drawn - - - - - - -	0·76	0·19	0·96	0·79	0·85
		Oxygen in solution when analysed, *i.e.*, after 5 days - -	0·83	0·04	0·87	0·74	0·69

Summary.—1. This effluent, when diluted with about 75 times its own volume of clean water moving in a slow to rapid current, did not give rise to smell.

2. The water was not materially deoxygenated through admixture with the effluent.

3. There were no deposits of objectionable mud in the river below the outfall, though the outfall ditch itself was considerably fouled.

4. Grey algal growth was present in the outfall ditch and at its outlet, but it could be seen in the river for more than a few yards.

5. Coarse fish were present in the river.

HUNTINGDON AND THE RIVER OUSE.

Population.—4,500.
Sewerage System.—Combined.
Dry weather Flow.—About 100,000 gallons per 24 hours.
Nature of Sewage.—A strong sewage containing brewery refuse.
Treatment.—The sewage passes through ½ inch grids and a grit settling tank before discharge.
Total capacity of grit settling tank.—6,250 gallons.

Sewage.—This is a brown turbid liquid, with a strong smell, and containing about 20 parts of suspended solids.

	Parts per 100,000.
Ammoniacal nitrogen	6·56
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	17·69
Dissolved oxygen taken up from water at 65° F.	
In 48 hours	30·8
In 5 days	47·5

Name of Stream.—The River Ouse.

Velocity.—The current velocity, as measured in fairly dry weather over a distance of about 6,500 feet, varied from 36 to 51 feet per minute; in flood time the current varied from 50 to over 150 feet per minute. In dry weather the current for the most part is slow at Huntingdon. The river rises only slowly in times of storm.

The width of the river varies from 70 to 200 feet, and the depth from 5 to over 20 feet. In the channel the depth is rarely under 6 feet.

The bed of the river is mainly clay. Water weeds are abundant in the shallower portions.

The flow of the river Ouse at Huntingdon in dry weather is about 96,000,000 gallons per 24 hours, giving a dilution to the sewage of about 960 to 1.

Effect of the Sewage Discharge.—Visits were paid in March, September, and December, 1909, July and October, 1910, and August, 1911.

The sewage is discharged into fairly deep water from a partially submerged outfall on the river bank.

There was a large deposit of putrid mud against and just below the outfall. This extended for something like 50 yards below the outfall on one side of the river.

In warm dry weather some of the mud rises to the surface and gives rise to slight local nuisance. In wet weather no objectionable conditions of this kind can be observed.

Grey algal growth extended along one side of the river below the outfall for about 100 yards.

There is a secondary sewage outfall, serving the New Town district, about a quarter of a mile below the main outfall. This discharges into a short ditch connected with the river.

The ditch itself was very much fouled, and some smell arose from it.

In the main river the effect of the discharge of the polluted ditch water is only very slight.

Samples drawn.	Approximate dilution of effluent by river water.		River water just above Outfall.	Sewage effluent	River water 300 yards below outfall.	River water 700 yards below outfall.	River water 1,760 yards below outfall.	River water 2,700 yards below outfall.
Mar. 10, 1909.	2400 to 1	Ammoniacal nitrogen	0·032	2·48	—	0·030	0·026	0·028
		Albuminoid nitrogen	0·04	0·69	—	0·04	0·04	0·04
		Nitric nitrogen	0·43	0·76	—	0·48	0·47	0·45
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·33	4·17	—	0·31	0·35	0·35
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	12·05	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·44	—	—	0·25	0·33	0·35
		Chlorine	2·92	8·41	—	2·80	2·75	2·80
		Suspended solids	2·8	10·3	—	3·2	3·3	3·0
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·14	0·31	—	1·13	1·10	1·14
Sept. 27, 1909.	1200 to 1	Ammoniacal nitrogen	0·005	6·20	0·011	—	0·011	0·005
		Albuminoid nitrogen	0·02	1·43	0·02	—	0·02	0·02
		Nitric nitrogen	0·07	—	0·14	—	0·15	0·12
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·21	5·91	0·22	—	0·22	0·21
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	13·03	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·09	39·50	0·09	—	0·06	0·11
		Chlorine	2·78	13·74	2·80	—	2·84	2·83
		Suspended solids	—	19·1	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·84	—	0·82	—	0·80	0·87
Dec. 1, 1909.	2000 to 1	Ammoniacal nitrogen	0·022	1·24	—	—	—	0·028
		Albuminoid nitrogen	0·02	1·22	—	—	—	0·02
		Nitric nitrogen	0·23	0·20	—	—	—	0·26
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·26	13·71	—	—	—	0·28
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	27·16	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·20	29·00	—	—	—	0·32
		Chlorine	2·55	4·30	—	—	—	2·53
		Suspended solids	—	150·0	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·10	0·00	—	—	—	1·07

Samples drawn.	Approximate dilution of effluent by river water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 700 yards below outfall.	River water 1,760 yards below outfall.	River water 2,700 yards below outfall.
July 28, 1910.	960 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·009	6·64	0·022	0·017	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·02	2·44	0·04	0·03	—	—
		Nitric nitrogen - - - - - - - - - - -	0·13	—	0·14	0·15	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·20	12·69	0·22	0·20	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	37·03	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·12	—	0·32	0·09	—	—
		Chlorine - - - - - - - - - - - - -	2·75	6·53	2·79	2·75	—	—
		Suspended solids - - - - - - - - - -	1·11	356·0	1·20	0·70	—	—
		Oxygen in solution when drawn - - - - - - -	0·73	0·00	0·71	0·91	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·76	—	0·68	0·64	—	—
Oct. 4, 1910.	960 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·008	—	—	0·010	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·02	—	—	0·03	—	—
		Nitric nitrogen - - - - - - - - - - -	0·16	—	—	0·13	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·18	—	—	0·19	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·07	—	—	0·10	—	—
		Chlorine - - - - - - - - - - - - -	3·02	—	—	2·98	—	—
		Suspended solids - - - - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days - -	0·79	—	—	0·75	—	—
Aug. 2, 1911.	960 to 1	Dissolved oxygen when drawn - - - - - -	0·67	—	0·64	0·58	—	—

Summary.—1. The Huntingdon sewage, when diluted with about 1,000 times its own volume of clean water moving in a slow to moderate current, did not give rise to smell.

2. The river water was not materially deoxygenated through admixture with the sewage.

3. There were deposits of putrid mud against both outfalls. In dry weather some smell arose from these, but it was local. In wet weather no smell could be detected.

4. Grey algal growth was present on one side of the river below each of the outfalls. It extended about 100 yards below the main outfall and 20 yards below the secondary outfall. It was not easy to see in the deep water.

5. Coarse fish were plentiful.

KENILWORTH AND THE FINHAM BROOK.

Population.—4,500.
Sewerage System.—Partially separate.
Dry weather Flow.—100,000 gallons per 24 hours.
Nature of Sewage.—Strong domestic sewage with much tannery waste.
Treatment.—Septic tanks followed by single or double percolating filters.

Total capacity of septic tanks	100,000 gallons.
Total cubic contents of percolating filters :—	
Primary	2,485 cube yards.
Secondary	940 ,, ,,
Total	3,425 ,, ,,

Effluent.—The effluent is a highly nitrated bright liquid with a very strong yellowish brown tint. It contains, on the average, about 5·0 parts of brown, well-coagulated, suspended matter.

It is of fairly uniform quality and composition, and non-putrescible upon incubation.

	Parts per 100,000.
Ammoniacal nitrogen	0·03
Nitric nitrogen	5·27
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·97
Dissolved oxygen taken up from water at 65° F. :	
In 48 hours	0·18
In 5 days	0·55

Name of Stream.—The Finham Brook, a tributary of the Warwickshire Avon.

Velocity.—The Finham Brook is a small, rather slow stream flowing in a bed composed of sand and mud.

The average current velocity, as measured in somewhat wet weather over a stretch of about one mile below the sewage outfall, was about 30 feet per minute.

The width of the stream varies from 6 to 15 feet, and the depth from a few inches to 2 feet 6 inches or 3 feet.

The average dry weather flow of the stream is about 1,500,000 gallons per 24 hours, which gives a dilution to the effluent of about 15 to 1.

The stream is liable to intermittent pollution from a skin dressing works above the outfall.

Effect of Effluent Discharge.—Owing to the intermittent discharge of polluting liquids in Kenilworth, the stream water is not always in a clean condition when it reaches the point at which the effluent is discharged. It is, however, fairly clean as a rule.

Visits paid in February, June, and August, 1909 ; May, August and September, 1910, and February, 1911.

Grey algal growth was usually present on the twigs, grass and stones above the outfall. If anything, the effect of the effluent discharge was to diminish the quantity of fungus in the stream, for this got gradually less from the outfall downwards. A mile below the outfall only traces of fungus were to be seen, and two miles below it was practically absent.

A mile below the outfall the first signs of green algal growth appeared, together with a chocolate-coloured growth, which occurred on most of the stones in the shallows. A green aquatic plant (*Ranunculus aquatilis*) was abundant in the shallows two miles below the outfall.

There was no nuisance from smell.

The pools below the outfall contained a good deal of brown-black mud.

Small fish were present in the stream.

Samples drawn.	Approximate dilution of effluent by stream water.		River water just above outfall.	Sewage effluent	River water 600 yards below outfall.	River water 1,300 yards below outfall.	River water 2,500 yards below outfall.	River water 3,500 yards below outfall.
Feb. 2, 1909.	20 to 1	Ammoniacal nitrogen	0·044	0·61	—	0·054	0·047	0·046
		Albuminoid nitrogen	0·03	0·24	—	0·05	0·04	0·04
		Nitric nitrogen	0·22	3·62	—	0·30	0·34	0·36
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·38	2·10	—	0·40	0·42	0·43
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·35	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·25	3·51	—	0·39	0·43	0·43
		Chlorine	2·10	49·00	—	2·70	2·75	2·76
		Suspended solids	—	4·5	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·04	0·00	—	0·97	1·03	0·99
June 28, 1909.	15 to 1	Ammoniacal nitrogen	0·063	0·360	—	0·032	—	—
		Albuminoid nitrogen	0·08	0·27	—	0·04	—	—
		Nitric nitrogen	0·23	4·85	—	0·60	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·70	2·58	—	0·44	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·97	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·70	1·85	—	0·31	—	—
		Chlorine	2·51	14·21	—	3·42	—	—
		Suspended solids	—	8·6	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·42	0·36	—	0·65	—	—

Samples drawn.	Approximate dilution of effluent by stream water.		River water just above outfall.	Sewage effluent	River water 600 yards below outfall.	River water 1,300 yards below outfall.	River water 2,500 yards below outfall.	River water 3,500 yards below outfall.
Aug. 22, 1909.	30 to 1	Ammoniacal nitrogen	0·029	0·020	—	0·018	—	—
		Albuminoid nitrogen	0·02	0·32	—	0·02	—	—
		Nitric nitrogen	0·13	4·56	—	0·36	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·36	2·77	—	0·30	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	4·40	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·26	0·75	—	0·23	—	—
		Chlorine	2·20	49·20	—	3·92	—	—
		Suspended solids	—	12·7	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·86	0·70	—	0·82	—	—
May 3, 1910.	20 to 1	Ammoniacal nitrogen	0·010	0·170	0·015	0·014	—	—
		Albuminoid nitrogen	0·03	0·27	0·03	0·03	—	—
		Nitric nitrogen	0·26	6·32	0·50	0·52	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	2·25	0·32	0·32	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·41	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·31	1·14	0·37	0·38	—	—
		Chlorine	2·10	21·44	2·86	2·80	—	—
		Suspended solids	2·4	11·1	2·1	2·0	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·26	0·49	1·23	1·19	—	—
Aug. 17, 1910.	20 to 1	Ammoniacal nitrogen	0·050	0·020	0·020	0·012	—	—
		Albuminoid nitrogen	0·03	0·09	0·03	0·02	—	—
		Nitric nitrogen	0·10	0·48	0·56	0·60	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·41	0·90	0·34	0·31	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·48	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·25	0·09	0·21	0·17	—	—
		Chlorine	2·42	45·50	4·56	4·79	—	—
		Suspended solids	0·94	2·80	1·10	2·15	—	—
		Oxygen in solution when drawn	0·57	0·70	0·64	0·65	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·48	0·66	0·70	0·66	—	—
Sept. 29, 1910.	15 to 1	Ammoniacal nitrogen	0·047	—	—	0·013	—	—
		Albuminoid nitrogen	0·09	—	—	0·02	—	—
		Nitric nitrogen	0·075	—	—	0·24	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·50	—	—	0·30	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	—	—	—	0·29	—	—
		Chlorine	3·21	—	—	2·97	—	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	0·60	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·40	—	—	0·66	—	—
Feb. 23, 1911.	30 to 1	Ammoniacal nitrogen	0·016	1·260	0·063	—	—	—
		Albuminoid nitrogen	0·03	0·51	0·05	—	—	—
		Nitric nitrogen	0·23	2·83	0·27	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·36	3·22	0·47	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	5·32	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·22	6·95	0·50	—	—	—
		Chlorine	1·80	21·23	2·72	—	—	—
		Suspended solids	2·6	15·7	3·0	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·11	0·25	1·02	—	—	—

Summary.—1. This effluent, when diluted with about 15 times its own volume of fairly clean water moving in a sluggish current, gave rise to no smell.

2. The water of the steam was not materially deoxygenated through admixture with the effluent.

3. A deposit of mud, formed in the pools below the effluent outfall, did not appear to give rise to nuisance.

4. The effluent did not increase the quantity of grey fungus present in the stream, but a chocolate-coloured growth flourished in the shallows about a mile below the outfall, and gave them a rather unsightly appearance.

5. The effluent appeared to cause a considerable development of *Ranunculus aquatilis.*

6. Small fish were present in the stream.

LINCOLN AND THE SOUTH DELPH.

Population.—47,000.
Sewerage System.—Combined.
Dry weather Flow.—1,500,000 gallons per 24 hours.
Nature of Sewage.—Domestic with trades waste.
Treatment.—Settling tanks followed by double contact beds or percolating filters or land.

Total capacity of tanks	1,800,000 gallons.
Total cubic content of filters:—	
Percolating filters	4,555 cubic yards.
Contact beds	24,630 ,, ,,
Total	29,185 ,, ,,
Total area of irrigable land	56 acres.

Effluent.—The effluent is a brownish and slightly opalescent liquid, which usually has a clean earthy smell.

It contains, as a rule, 2·0 to 3·0 parts of well coagulated suspended matter per 100,000, but this is largely augmented in times of storm.

It is of fairly even quality and composition and is uniformly non-putrescible on incubation.

	Parts per 100,000.
Ammoniacal nitrogen	1·58
Nitric nitrogen	1·53
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·64
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	0·52
In 5 days	1·75

Name of Stream.—The South Delph, an artificial by-pass from the river Witham.

Velocity.—The mean velocity of the current, as measured in fairly dry weather close to the outfall, was 30 to 40 feet per minute. A mile below the outfall the current velocity was 20 feet per minute or less.

The current is therefore slow to sluggish.

The width of the Delph is about 25 feet, and the depth of water varies from 1 to 4 feet.

The average dry weather flow is about 7,500,000 gallons per day, so that the dilution of the effluent is about 5 to 1.

In wet weather the dilution may be 12 or 15 to 1 or more.

Owing to its use for condensing purposes, the Delph water is often perceptibly warm. Traces of oil were always present on the surface of the water.

Effect of Effluent Discharge.—Visits paid in April (twice), June (three times), July and October, 1909, June and October, 1910, and May (twice) July and September, 1911.

Speaking generally, there was no nuisance from smell below the outfall, but on one occasion, after a period of very dry weather, a slight but distinct smell was observed.

The bed of the Delph was considerably fouled with putrescible mud, and in very dry weather when the water was low it had an unpleasant and dirty appearance.

Much grey fungus was present below the outfall, and in summer, a mile and more below the outfall, the development of green algal growth was so great as to impede the flow of water.

It is to be noted that at Washingborough Station, a mile below the outfall, some untreated sewage gains access to the Delph.

Samples drawn.	Approximate dilution of effluent with Delph water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 1,400 yards below outfall.	River water 2,200 yards below outfall.	River water 3,000 yards below outfall.
April 29, 1909.	5 to 1	Ammoniacal nitrogen	0·023	1·63	0·282	0·164	0·214	0·190
		Albuminoid nitrogen	0·02	0·26	0·06	0·04	0·04	0·04
		Nitric nitrogen	0·34	2·80	0·70	0·65	0·52	0·54
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·25	1·09	0·41	0·39	0·38	0·33
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·16	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·20	2·98	0·60	0·40	0·28	0·22
		Chlorine	4·22	15·33	5·97	5·61	5·48	5·03
		Suspended solids	—	3·6	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·34	0·68	1·23	1·13	1·13	1·06
June 1, 1909.	10 to 1	Ammoniacal nitrogen	0·070	2·380	0·588	0·394	0·668	—
		Albuminoid nitrogen	0·05	0·29	0·09	0·08	0·09	—
		Nitric nitrogen	0·21	0·78	0·38	0·35	0·53	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·47	0·79	0·51	0·47	0·54	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·29	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·59	0·72	0·60	0·43	0·49	—
		Chlorine	6·09	12·20	7·49	6·43	7·40	—
		Suspended solids	3·0	2·0	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·13	0·52	1·01	0·75	0·56	—
June 29, 1909.	10 to 1	Ammoniacal nitrogen	0·037	1·370	—	0·214	0·281	—
		Albuminoid nitrogen	0·03	0·16	—	0·05	0·06	—
		Nitric nitrogen	0·42	0·76	—	0·50	0·58	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·44	0·85	—	0·55	0·57	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·24	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·20	0·72	—	0·22	0·29	—
		Chlorine	4·06	11·87	—	4·91	5·14	—
		Suspended solids	0·42	2·30	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·79	0·62	—	0·53	0·48	—

Samples drawn.	Approixmate dilution of effluent with Delph water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 1,400 yards below outfall.	River water 2,200 yards below outfall.	River water 3,000 yards below outfall.
July 26, 1909.	5 to 1	Ammoniacal nitrogen	0·020	1·720	0·484	0·664	0·554	—
		Albuminoid nitrogen	0·03	0·30	0·06	0·06	0·06	—
		Nitric nitrogen	0·05	2·86	0·68	0·78	0·65	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	1·29	0·47	0·45	0·45	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·60	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·15	4·80	0·45	—	0·50	—
		Chlorine	6·01	14·70	8·55	9·11	8·07	—
		Suspended solids	—	3·7	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·40	0·49	0·70	0·58	0·77	—
Oct. 28, 1909.	15 to 1	Ammoniacal nitrogen	0·022	0·860	0·037	0·030	0·029	—
		Albuminoid nitrogen	0·08	0·22	0·08	0·06	0·06	—
		Nitric nitrogen	0·20	2·03	0·29	0·23	0·21	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·84	0·93	0·85	0·56	0·59	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·67	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	—	2·65	0·39	0·27	0·32	—
		Chlorine	2·72	15·33	2·29	2·30	2·31	—
		Suspended solids	3·3	2·7	18·2	8·9	9·6	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	0·81	0·80	0·91	0·89	0·85	—
June 14, 1910.	5 to 1	Ammoniacal nitrogen	0·008	0·830	0·180	0·160	—	—
		Albuminoid nitrogen	0·04	0·16	0·08	0·07	—	—
		Nitric nitrogen	0·15	2·33	0·68	0·82	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·37	0·87	0·50	0·59	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·52	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·24	2·22	0·97	—	—	—
		Chlorine	4·01	13·76	5·69	5·73	—	—
		Suspended solids	0·34	1·6	0·6	0·8	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·98	—	0·99	0·59	—	—
Oct. 6, 1910.	3 to 1	Ammoniacal nitrogen	0·162	1·140	0·807	0·548	0·849	—
		Albuminoid nitrogen	0·04	0·19	0·14	0·10	0·10	—
		Nitric nitrogen	0·18	3·02	2·06	1·34	0·80	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·37	1·19	0·89	0·62	0·58	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·13	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·12	3·31	1·27	0·61	0·45	—
		Chlorine	5·45	20·25	12·03	9·61	8·64	—
		Suspended solids	1·9	3·6	2·2	1·2	1·1	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	0·33	0·25	0·33	0·15	0·14	—
May 9, 1911.	5 to 1	Ammoniacal nitrogen	0·029	0·370	0·054	0·079	0·072	—
		Albuminoid nitrogen	0·03	0·28	0·06	0·05	0·05	—
		Nitric nitrogen	0·23	2·80	0·81	0·53	0·64	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	1·46	0·47	0·46	0·45	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·68	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·23	1·85	0·62	0·63	0·60	—
		Chlorine	3·51	12·70	4·80	4·60	4·56	—
		Suspended solids	1·4	5·7	1·7	1·8	1·6	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·12	0·42	1·33	1·15	1·14	—
May 22, 1911.	5 to 1	Ammoniacal nitrogen	0·017	—	—	0·162	0·177	—
		Albuminoid nitrogen	0·05	—	—	0·05	0·05	—
		Nitric nitrogen	0·27	—	—	0·82	0·80	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·40	—	—	0·37	0·37	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·65	—	—	0·86	0·50	—
		Chlorine	4·01	—	—	5·44	5·40	—
		Suspended solids	2·0	—	—	1·1	1·2	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·20	—	—	1·29	1·03	—

Samples drawn.	Approximate dilution of effluent with Delph water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 1,400 yards below outfall.	River water 2,200 yards below outfall.	River water 3,000 yards below outfall.
July 18, 1911.	5 to 1	Ammoniacal nitrogen	0·168	0·150	0·174	0·088	0·121	—
		Albuminoid nitrogen	0·04	0·17	0·07	0·05	0·05	—
		Nitric nitrogen	0·20	4·67	1·64	0·92	1·18	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·47	1·41	0·66	0·57	0·59	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·19	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·39	0·84	0·78	0·33	0·54	—
		Chlorine	5·55	17·24	9·80	8·87	9·00	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawu	1·14	0·68	0·91	0·73	0·83	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·27	0·63	0·91	0·69	0·85	—
Sept. 23, 1911.	5 to 1	Ammoniacal nitrogen	0·080	0·344	0·320	0·244	0·444	0·444
		Albuminoid nitrogen	0·03	0·13	0·13	0·08	0·06	0·06
		Nitric nitrogen	0·31	3·74	2·89	2·08	1·26	1·72
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·26	0·95	0·94	0·52	0·46	0·55
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·52	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·28	1·21	0·92	0·31	0·52	0·32
		Chlorine	4·36	17·02	17·17	11·76	9·94	11·44
		Suspended solids	—	—	2·1	0·7	0·7	1·0
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·10	0·73	0·75	0·80	0·53	0·70

Summary.—1. This effluent, when diluted with about five times its own volume of fairly clean water, did not give rise to smell, even though the stream current of the Delph is sluggish.

In very dry weather, when the dilution is less than this, say 2·5 to 1, slight but distinct smell did arise.

2. From the laboratory tests it may reasonably be inferred that under normal conditions the water of the Delph is distinctly but not materially deoxygenated.

3. In storm times much suspended matter was dis- with the sewage effluent. The bed of the Delph was considerably fouled with black mud, resulting from the deposition and decay of this suspended matter.

4. Grey algal growth was plentiful for a quarter of a mile below the outfall. Under ordinary conditions it was practically absent a mile below the outfall, but in very dry weather it may extend for 2 miles or more.

A mile below the outfall there was in summer a great development of green algal growth.

5. Coarse fish were present in the Delph below the outfall.

MALTON (YORKS.) AND THE RIVER DERWENT.

Population.—9,000 (Malton and Norton).
Sewerage System.—Combined.
Dry weather Flow.—300,000 gallons (Malton and Norton) per 24 hours.
Nature of Sewage.—Strong domestic.
Treatment.—None.

Sewage.—The sewage is a strong soapy one, containing fully 40 parts of suspended solids. It is a dark turbid liquid with a strong sewage smell.

	Parts per 100,000.
Ammoniacal nitrogen	5·76
Oxygen absorbed from $\frac{N}{8}$ permanganates in 4 hours at 80° F.	16·64
Dissolved oxygen taken up from water at 65° F:	
In 48 hours	23·2
In 5 days	44·5

Name of Stream.—The river Derwent.

Velocity.—The mean velocity of the current, as measured over a distance of 5,000 feet, when the river was high, was about 65 feet per minute. In dry weather the current is moderately rapid.

The width of the river varies from 50 to 70 feet, and the depth from about 3 to 10 feet, with an average depth in the centre of the channel of about 6 feet.

The river bed is chiefly clay. The dry weather flow of the Derwent at Malton is about 120,000,000 gallons per 24 hours, this volume giving a dilution to the sewage of about 400 to 1.

The river rises rather rapidly in wet weather. A rate of flow of nearly 240,000,000 gallons was measured during the observations.

Effect of Sewage Discharge.—Visits paid in May and December, 1909, June and October, 1910, and February, May and August, 1911.

The sewage is discharged from a number of outfalls, which extend from about a mile above Malton Bridge to about the same distance below.

The river also receives the waste liquors from two breweries, some slaughter-house refuse, and the washings from the cattle market. These are all intermittent discharges.

Nearly all the outfalls are submerged, but in dry weather some of them may become uncovered and give rise to local nuisance. Below the main outfalls there were deposits of grit and putrid mud. These are occasionally removed by the authority. When the river is low some of the putrid mud rises to the surface of the water and floats down stream, buoyed up by gas bubbles. Pieces of fœcal matter could also be seen in the water, together with barley husks, etc., from the breweries.

Grey algal growth could be seen on submerged grass and twigs for a mile and a half below Malton Bridge, but it was not present in sufficient quantity to be obtrusive.

Fish were plentiful in the river.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 1,200 yards below outfall.	River water 2,000 yards below outfall.
May 3, 1909.	1600 to 1	Ammoniacal nitrogen	0·007	3·080	0·010	0·005	0·006
		Albuminoid nitrogen	0·02	1·24	0·02	0·02	0·02
		Nitric nitrogen	0·15	0·28	0·12	0·16	0·15
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·23	7·82	0·23	0·23	0·24
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	22·38	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·20	45·75	0·16	0·16	0·20
		Chlorine	1·96	7·43	1·87	1·86	1·81
		Suspended solids	1·28	52·00	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·11	0·00	1·10	1·04	1·07
June 14, 1910.	500 to 1	Ammoniacal nitrogen	0·009	4·080	0·008	—	—
		Albuminoid nitrogen	0·02	0·81	0·03	—	—
		Nitric nitrogen	0·14	—	0·15	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·17	7·80	0·21	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	15·47	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·16	55·40	0·41	—	—
		Chlorine	1·76	8·20	1·83	—	—
		Suspended solids	1·10	30·00	2·30	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·84	—	0·74	—	—
Oct. 5, 1910.	400 to 1	Ammoniacal nitrogen	0·004	4·40	0·013	0·012	0·012
		Albuminoid nitrogen	0·01	1·22	0·02	0·02	0·02
		Nitric nitrogen	0·06	—	0·07	0·08	0·07
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·37	9·55	0·39	0·40	0·39
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	20·95	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·07	39·5	0·14	0·10	0·07
		Chlorine	1·53	8·00	1·61	1·66	1·62
		Suspended solids	0·90	40·50	1·60	1·40	1·20
		Oxygen in solution when drawn	0·90	0·00	0·87	0·87	0·84
		Oxygen in solution when analysed, *i.e.*, after 6 days	0·86	0·00	0·79	0·74	0·72

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 1,200 yards below outfall.	River water 2,000 yards below outfall.
Feb. 8, 1911.	400 to 1	Ammoniacal nitrogen	0·007	7·000	0·014	—	—
		Albuminoid nitrogen	0·01	2·32	0·01	—	—
		Nitric nitrogen	0·02	0·12	0·14	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·23	12·77	0·19	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	30·11	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·14	49·80	0·17	—	—
		Chlorine	1·78	10·24	1·80	—	—
		Suspended solids	1·70	115·40	1·30	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·16	—	1·13	—	—
May 31, 1911.	400 to 1	Ammoniacal nitrogen	0·008	9·680	—	0·042	0·043
		Albuminoid nitrogen	0·01	1·50	—	0·03	0·02
		Nitric nitrogen	0·10	—	—	0·08	0·11
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·12	9·07	—	0·23	0·18
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	16·30	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·05	32·00	—	0·24	0·18
		Chlorine	1·53	9·06	—	1·57	1·53
		Suspended solids	1·40	27·60	—	2·00	1·40
		Oxygen in solution when drawn	0·94	—	—	0·72	0·75
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·96	—	—	0·58	0·58
Aug. 11, 1911.	400 to 1	Ammoniacal nitrogen	0·007	7·560	0·011	0·016	0·011
		Albuminoid nitrogen	0·02	1·56	0·03	0·03	0·02
		Nitric nitrogen	0·07	0·00	0·06	0·11	0·09
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·18	12·10	0·21	0·19	0·19
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	21·07	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·13	76·00	0·34	0·28	0·19
		Chlorine	0·17	9·12	1·78	1·72	1·73
		Suspended solids	—	25·2	—	—	—
		Oxygen in solution when drawn	0·81	—	0·73	0·69	0·66
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·76	—	0·56	0·59	0·59

Summary.—1. This strong sewage when diluted with about 400 times its own volume of clean water did not give rise to smell.

2. The water was not materially deoxygenated through admixture with the sewage.

3. In dry weather deposits of putrifying mud were near the main outfalls, and gave rise to smell on occasion.

4. Grey algal growth was present in small quantity for about a mile and a half below Malton Bridge, or a mile below the lowest outfall.

5. Fish were plentiful in the river below Malton.

MIDDLETON-IN-TEESDALE AND THE RIVER TEES.

Population.—2,160.

Sewerage System.—Partially separate.

Dry weather Flow.—27,500 gallons per 24 hours.

Nature of Sewage.—Domestic, mainly slop water.

Treatment.—Grit settlement and closed septic tank followed by percolating filters, which are fed by means of Stoddart trays. Some sewage is occasionally distributed over land.

Total capacity of grit chamber	2,362 gallons.
Total capacity of septic tanks	45,700 ,,
Total	48,062 ,,
Total cubic content of filters	200 yards.

Effluent.—The effluent is an opalescent liquid with a brownish tint. It occasionally smells of sewage, and contains on the average about 6·0 parts of suspended matter per 100,000.

It is of variable quality and composition; 4 samples out of 9 putrefied on incubation.

	Parts per 100,000.
Ammoniacal nitrogen	2·04
Nitric nitrogen	0·27
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	2·33
Dissolved oxygen taken up from water at 65° F.	
In 48 hours	1·07
In 5 days	3·20

Name of Stream.—The river Tees.

Velocity.—The Tees at Middleton is a broad shallow river with deep rocky pools; the bed is composed of loose stones, boulders and rocks.

The current velocity is very high in the centre of the stream, but sluggish in the pools and the marginal shallows.

The average current velocity, as measured in dry weather over a stretch of about half a mile below the outfall, was from 50 to 60 feet per minute.

The volume of water in dry weather averages about 40,000,000 gallons per 24 hours, and this gives a dilution to the sewage effluent of about 1,400 to 1.

The flow of the river is subject to exceptionally large and rapid variation.

Effect of Effluent Discharge.—The outfall is at the side of the river and the effluent is discharged among loose stones where there is comparatively little dilution.

For a distance of about 50 yards there was a deposit of black putrefying mud and much grey fungus. A slight but distinct smell was observed close to the outfall on one occasion.

Three hundred yards below the outfall the mixture of effluent and river water is complete, and from this point onwards there is no sensible sign of pollution.

Samples drawn.	Approximate dilution of effluent by river water.		River water just above outfall.	Sewage effluent	River water 50 yards below outfall.	River water 300 yards below outfall.	River water 1,760 yards below outfall.
Mar. 4, 1909.	1400 to 1	Ammoniacal nitrogen	0·002	2·550	0·297	0·006	0·009
		Albuminoid nitrogen	0·005	0·27	0·04	0·01	0·01
		Nitric nitrogen	0·03	0·14	0·07	0·04	0·05
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·09	1·80	0·23	0·12	0·12
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·38	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·12	7·90	0·60	0·18	0·00
		Chlorine	0·68	4·15	1·09	0·70	0·72
		Suspended solids	0·16	6·20	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·18	0·08	1·08	1·26	1·34
June 4, 1909.	1400 to 1	Ammoniacal nitrogen	0·002	3·100	—	0·005	—
		Albuminoid nitrogen	0·01	0·35	—	0·01	—
		Nitric nitrogen	0·02	0·15	—	0·02	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·36	2·33	—	0·36	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	4·66	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·15	7·00	—	0·08	—
		Chlorine	0·55	5·06	—	0·57	—
		Suspended solids	—	14·40	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·13	0·10	—	1·09	—
Dec. 29, 1911.	2800 to 1	Ammoniacal nitrogen	0·003	1·010	—	0·005	0·003
		Albuminoid nitrogen	0·01	0·18	—	0·01	0·01
		Nitric nitrogen	0·04	0·32	—	0·04	0·04
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·25	0·62	—	0·28	0·28
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·87	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·16	1·76	—	0·08	0·09
		Chlorine	0·57	2·70	—	0·54	0·56
		Suspended solids	—	3·20	—	—	—
		Oxygen in solution when drawn	1·15	0·44	—	1·05	1·06
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·15	0·00	—	1·04	1·05

Summary.—1. This effluent, when diluted with 1,400 times its own volume of clean water, flowing in a current of high velocity, did not give rise to smell.

2. The water was not sensibly deoxygenated through the admixture of the effluent.

3 and 4. The outfall is at the side of the river and the effluent is usually discharged amongst loose stones where the dilution is comparatively small.

Immediately below the outfall there was much grey fungus amongst the stones and a deposit of black putrefying mud.

Beyond the point at which complete mixing occurs neither deposit nor fungus was observed.

5. There were trout and salmon in the river above and below the outfall.

NUNEATON AND THE RIVER ANKER.

Population.—32,000.
Sewerage System.—Partially separate.
Dry weather Flow.—800,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—Settlement followed by either:—
(1) Double contact beds.
(2) Single contact beds and percolating filters.
(3) Percolating filters.

The effluent from each of the above processes is finally filtered through land.

Total combined tank capacity	150,000 gallons.
Primary contact beds	9,331 cube yards.
Secondary contact beds	6,665 ,, ,,
Percolating filters	7,268 ,, ,,
Total	23,264 ,, ,,
Total irrigable area	34·5 acres.

Effluent.—The effluent is derived from a strong sewage. It is a faintly opalescent liquid with a brownish tint. It has a clean earthy smell, and contains on the average about 2 parts suspended matter. It is of a somewhat variable composition; three samples out of sixteen were putrescible on incubation.

	Parts per 100,000.
Ammoniacal nitrogen	1·05
Nitric nitrogen	0·74
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·22
Dissolved oxygen taken up from water at 65° F.	
In 48 hours	0·42
In 5 days	1·58

Name of Stream.—The river Anker, a branch tributary of the Trent.

Velocity.—The river Anker at Nuneaton is a small sluggish stream contained in a soft muddy bed.

The mean current velocity, measured in fairly dry weather over a stretch of about three quarters of a mile, was found to be approximately 20 feet per minute.

The width of the stream below the sewage works varies from 15 to 25 feet; the depth is fairly uniform at about 2 feet 6 inches.

The water of the stream is subject to intermittent pollution with trades waste and surface water in Nuneaton, a distance of three miles above the outfall.

The average flow of water in the stream in dry weather is about 1,700,000 gallons, which gives a dilution to the effluent of approximately 2 to 1.

Effect of the Effluent Discharge.—Visits were paid in May, 1909, January, April and September, 1910, and January, May and July, 1911.

The effluent is discharged from three outfalls.

There was some old grey algal growth above the outfalls. Just below each of the outfalls there was a strong development of new growth, which extended in moderate quantity for about half a mile below the lowest outfall.

At certain seasons of the year green algal growth, duck weed, etc., were present in great quantities below the outfalls. The algal growth swarmed with aquatic insects.

In warm dry weather the water of the river was very dark in appearance.

In the sluggish reaches of river below the outfalls there were thin deposits of grey mud, which in warm weather were frequently covered with small flies.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 200 yards below outfall.	River water 1,200 yards below outfall.	River water 2,000 yards below outfall.	Rive wate 3,00 yard belo outfa
May 6, 1909.	5 to 1	Ammoniacal nitrogen	0·032	1·310	0·224	0·272	0·408	—
		Albuminoid nitrogen	0·04	0·21	0·06	0·07	0·08	—
		Nitric nitrogen	0·32	0·49	0·36	0·38	0·43	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·32	1·13	0·48	0·53	0·55	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·83	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·17	0·50	0·53	0·57	0·69	—
		Chlorine	8·19	18·66	9·75	10·18	11·79	—
		Suspended solids	0·70	2·40	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	1·02	0·21	0·78	0·56	0·56	—
Jan. 13, 1910.	6 to 1	Ammoniacal nitrogen	0·140	0·600	0·149	—	0·149	—
		Albuminoid nitrogen	0·05	0·14	0·04	—	0·05	—
		Nitric nitrogen	0·31	1·48	0·32	—	0·29	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·38	0·61	0·39	—	0·38	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·65	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·46	1·10	0.38	—	0·34	—
		Chlorine	3·25	13·04	3·54	—	3·34	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	0·96	0·58	0·98	—	0·93	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	0·95	0·27	0·95	—	0·86	—

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 200 yards below outfall.	River water 1,200 yards below outfall.	River water 2,000 yards below outfall.	River water 3,000 yards below outfall.
April 27, 1910.	3 to 1	Ammoniacal nitrogen	0·206	1·03	0·352	—	0·326	—
		Albuminoid nitrogen	0·05	0·28	0·06	—	0·07	—
		Nitric nitrogen	0·38	1·43	0·42	—	0·47	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·41	1·56	0·56	—	0·55	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·54	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·39	3·18	0·48	—	0·54	—
		Chlorine	5·06	15·26	6·44	—	6·49	—
		Suspended solids	0·90	5·40	3·20	—	1·60	—
		Oxygen in solution when drawn	0·81	—	0·69	—	0·64	—
		Oxygen in solution when analysed, *i.e.*, after 5 days	0·82	—	0·54	—	0·60	—
Sept. 29, 1910.	3 to 1	Ammoniacal nitrogen	0·008	2·050	—	0·174	—	—
		Albuminoid nitrogen	0·03	0·16	—	0·05	—	—
		Nitric nitrogen	0·31	0·46	—	0·23	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·37	1·50	—	0·55	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·19	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·22	2·70	—	0·76 + x	—	—
		Chlorine	7·52	22·74	—	10·16	—	—
		Suspended solids	—	1·8	—	—	—	—
		Oxygen in solution when drawn	0·59	—	—	0·21	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·65	0·18	—	0·30	—	—
an. 24, 1911.	3 to 1	Ammoniacal nitrogen	0·182	2·260	0·376	—	—	—
		Albuminoid nitrogen	0·05	0·31	0·08	—	—	—
		Nitric nitrogen	0·32	0·32	0·56	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·35	1·40	0·55	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·65	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·37	3·20	0·68	—	—	—
		Chlorine	3·75	15·22	5·20	—	—	—
		Suspended solids	1·0	3·4	3·4	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·89	0·22	0·80	—	—	—
ay 18, 1911.	3 to 1	Ammoniacal nitrogen	0·042	1·280	0·407	—	0·712	—
		Albuminoid nitrogen	0·04	0·27	0·09	—	0·13	—
		Nitric nitrogen	0·26	2·93	0·91	—	0·78	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·41	2·56	0·97	—	0·98	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·87	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·28	2·92	0·95	—	0·84	—
		Chlorine	6·56	25·48	12·07	—	12·32	—
		Suspended solids	1·3	4·9	1·7	—	1·1	—
		Oxygen in solution when drawn	0·58	0·28	0·41	—	0·14	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·74	0·14	0·40	—	0·24	—
uly 17, 1911.	3 to 1	Ammoniacal nitrogen	0·014	5·500	0·316	0·202	—	0·486
		Albuminoid nitrogen	0·05	0·53	0·11	0·07	—	0·09
		Nitric nitrogen	0·18	—	1·80	0·47	—	0·55
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·52	3·99	0·85	0·75	—	0·52
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	6·86	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·20	11·15	0·65	0·52	—	1·00
		Chlorine	9·18	22·34	12·68	11·80	—	18·57
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	0·83	0·00	0·16	0·25	—	0·16
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·68	0·00	0·20	0·29	—	0·20

Summary.—1. This effluent, when diluted with about twice its own volume of only moderately clean water, moving in a sluggish current, did not give rise to smell.

2. The water of the steam was at times seriously deoxygenated through admixture with the effluent.

3. There was a thin deposit of mud in the sluggish reach below the outfalls. No nuisance from smell was caused by this, but it no doubt helped to deoxygenate the water.

4. Grey algal growth was present in the stream in considerable quantity for about half a mile below the outfalls. At certain seasons of the year green algal growth was abundant for a mile below the outfalls, and it usually swarmed with aquatic life.

5. Fish were absent or scarce in the sluggish reach below the outfall.

OLLERTON AND THE RIVER MAUN.

Population.—690 (not all draining to the river).
Sewerage System.—Combined.
Dry weather Flow.—8,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—None. There is one main sewer outfall, but the sewage from various houses is also discharged into the river.

Crude Sewage.—The sewage is of a soapy character and rather weak. It varies greatly in strength and volume throughout the day. Only two samples were examined.

	Parts per 100,000.
Ammoniacal nitrogen	0·78
Total nitrogen	2·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 60° F.	4·16
Dissolved oxygen taken up from water at 65° F.	
In 48 hours	—
In 5 days	9·88
Suspended solids	14·3

Name of Stream.—The River Maun, a small branch tributary of the Trent.

Velocity.—The River Maun is a small moderately rapid stream with a sandy bed. It is well stocked with trout and grayling.

Its mean current velocity below the outfall is about 50 feet per minute.

The width varies from about 20 to 25 feet; the depth varies from 12 to 18 inches. There are few deep pools.

The flow in dry weather is about 8,000,000 gallons per 24 hours, which gives a dilution to the sewage of about 1,000 to 1.

The water of the stream is normally clear and bright, but it is evidently subject on occasion to considerable pollution above Ollerton.

Effect of Crude Sewage Discharge.—Visits were paid in April and November, 1909, December, 1911, and March, May and June, 1912. The outfall is at the side of the stream, and the sewage is discharged into water about 2 feet deep. Immediately against the outfall there is a black deposit of sewage mud, but this fouling of the river bed is of an entirely local character, and, generally speaking, the bed of the river is fairly clean below the outfall.

About 50 yards below the outfall there is a weir. On the outfall side of the stream, between the outfall and the weir, and on the weir itself grey fungus is plentiful. The fungus can be traced for about 250 yards below the outfall, but no farther.

No nuisance from smell was observed.

Green water-weeds are plentiful, both above and below Ollerton.

Samples drawn.	Approximate dilution of Sewage with river water.		River water just above outfall.	Sewage effluent	River water 250 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	River water 3,500 yards below outfall.
April 22, 1909.	1000 to 1	Ammoniacal nitrogen	0·009	1·170	0·008	0·005	0·005	—
		Albuminoid nitrogen	0·03	0·33	0·03	0·02	0·02	—
		Nitric nitrogen	0·52	0·12	0·47	0·50	0·47	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·24	3·70	0·24	0·23	0·23	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	6·32	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·13	13·70	0·26	0·27	0·30	—
		Chlorine	3·39	6·51	3·07	2·88	2·90	—
		Suspended solids	0·85	14·30	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·07	0·05	1·07	1·07	1·07	—
Nov. 16, 1909.	1500 to 1	Ammoniacal nitrogen	0·175	0·380	—	—	0·160	—
		Albuminoid nitrogen	0·03	0·16	—	—	0·03	—
		Nitric nitrogen	0·55	0·55	—	—	0·66	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·31	—	—	—	0·26	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·00	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·61	6·05	—	—	0·08	—
		Chlorine	3·80	4·80	—	—	3·63	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·01	0·24	—	—	0·55	—
Dec. 5, 1911.	2000 to 1	Ammoniacal nitrogen	0·280	—	0·250	—	0·250	—
		Albuminoid nitrogen	0·07	—	0·04	—	0·04	—
		Nitric nitrogen	0·61	—	0·54	—	0·56	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·30	—	0·22	—	0·22	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·86	—	0·93	—	0·92	—
		Chlorine	3·50	—	3·11	—	3·33	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·87	—	1·00	—	1·05	—

Samples drawn.	Approximate dilution of Sewage with river water.		River water just above outfall.	Sewage effluent	River water 250 yards below outfall.	River water 1,000 yards below outfall.	River water 2,300 yards below outfall.	River water 3,500 yards below outfall.
Mar. 4, 1912.	3000 to 1	Ammoniacal nitrogen	0·026	—	0·026	—	—	—
		Albuminoid nitrogen	0·04	—	0·03	—	—	—
		Nitric nitrogen	0·51	—	0·51	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·41	—	0·29	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·75	—	0·38	—	—	—
		Chlorine	1·42	—	2·65	—	—	—
		Suspended solids	1·8	—	1·7	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·03	—	1·03	—	—	—
May 29, 1912.	1000 to 1	Ammoniacal nitrogen	0·010	—	0·008	0·009	0·008	0·008
		Albuminoid nitrogen	0·02	—	0·02	0·02	0·02	0·02
		Nitric nitrogen	0·49	—	0·59	0·56	0·50	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	—	0·16	0·15	0·12	0·14
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·15	—	0·18	0·16	0·16	0·13
		Chlorine	2·31	—	2·77	2·64	2·83	2·48
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	0·91	—	1·00	0·99	1·05	0·99
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·87	—	0·95	0·98	0·98	0·95
June 5, 1912	2000 to 1	Ammoniacal nitrogen	0·031	—	—	—	—	—
		Albuminoid nitrogen	0·06	—	—	—	—	—
		Nitric nitrogen	0·35	—	—	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·67	—	—	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·25	—	—	—	—	—
		Chlorine	1·90	—	—	—	—	—
		Suspended solids	5·10	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·79	—	—	—	—	—
June 19, 1912.	1000 to 1	Ammoniacal nitrogen	0·014	—	0·008	0·011	—	—
		Albuminoid nitrogen	0·02	—	0·02	0·02	—	—
		Nitric nitrogen	0·60	—	0·63	0·60	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·20	—	0·20	0·22	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·12	—	0·10	0·09	—	—
		Chlorine	2·74	—	3·12	3·46	—	—
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	0·88	—	0·99	0·96	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·85	—	0·94	0·92	—	—

NOTE.—The sewage effluent from the town of Mansfield is discharged into the river Maun some 10 or 12 miles above Ollerton. Up to December 19th, 1911, when a new purification works was brought into operation, the Mansfield sewage was irrigated over flood meadows before being discharged, and on occasion unpurified sewage undoubtedly found its way into the river. Some such sudden and unusual pollution must account for the bad quality of the water samples drawn at Ollerton in November, 1909, and December, 1911. The figures for these samples have been excluded from the averages for Ollerton given in Part II. If they had been included the average figures would have misrepresented the normal quality of the river water.

Summary.—1. This weak sewage, when diluted with 1,000 times its own volume of clean water moving in a moderately rapid current did not give rise to smell.

2. The water of the river was not materially deoxygenated through admixture with the sewage.

3. Except for a small local deposit of sewage mud against the outfall, no sensible fouling of the river bed was noticed. Pieces of paper and matches were, however, seen entangled in the water-weeds for at least a mile.

4. Grey algal growth was plentiful on the outfall side of the river for about 50 yards. It could be traced for a distance of 250 yards, but not farther. Green algal growth was present in fair quantity, both above and below the outfall, and various aquatic plants were plentiful throughout the whole stretch of river examined.

5. Trout were plentiful in the water both above and below the outfall.

PICKERING AND THE PICKERING BECK.

Population.—About 2,000 (400 houses).
Sewerage System.—Combined.
Dry weather Flow.—About 10,000 gallons per 24 hours.
Treatment.—None.

Crude Sewage.—The sewage as discharged into the beck at Hungate Bridge is rather under average strength. It is a brownish, soapy liquid with a strong sewage smell, and containing from 15 to 20 parts of suspended matter per 100,000.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	3·91
Nitric nitrogen - - - - - - -	0·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	7·61
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours - - - - - - -	14·3
In 5 days - - - - - - - -	26·3

Name of Stream.—Pickering Beck, a tributary of the Yorkshire Derwent.

Velocity.—There is one mill weir immediately above the town and two some little distance below it.

The mean velocity in the natural bed of the beck is from 90 to 100 feet per minute in fairly dry weather. For some distance behind each of the weirs the velocity is reduced to something like 20 or 30 feet per minute.

The beck is from 15 to 20 feet wide. It varies in depth from a few inches to something like 5 feet, this variation being mainly due to the weirs.

The beck may be very much swollen in storm time.

In dry weather the flow of the river is about 10,600,000 gallons per 24 hours, giving a dilution to the sewage of about 1,060 to 1.

Effect of Sewage Discharge.—Visits paid in May, June and December, 1909, and June and October, 1910.

Immediately below the main outfall at Hungate Bridge, where there is a shallow eddy, there was a good deal of deposit and fungus on the stones. The water was also visibly fouled here, and a distinct smell could be noticed.

From 100 yards or so below Hungate Bridge, where mixing is complete, the only sign of pollution was the presence in the water of grey algal growth. This extended for about a quarter of a mile, or rather more, below Hungate Bridge. It was not present in noticeable quantity. Trout were present in the stream below Pickering.

Samples drawn.	Approximate dilution of sewage with Beck water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 600 yards below outfall.	River water 2,000 yards below outfall.	River water 3,000 yards below outfall.
May 4, 1909.	1700 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·003	1·060	—	0·008	0·008	0·008
		Albuminoid nitrogen - - - - - - - - - -	0·01	0·39	—	0·02	0·01	0·01
		Nitric nitrogen - - - - - - - - - - -	0·13	0·00	—	0·10	0·11	0·09
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·13	2·55	—	0·19	0·18	0·19
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	5·32	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·06	15·60	—	0·21	0·15	0·16
		Chlorine - - - - - - - - - - - - -	1·71	2·61	—	1·71	1·67	1·73
		Suspended solids - - - - - - - - - -	0·45	22·20	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	1·08	0·00	—	1·02	1·11	1·05
June 29, 1909.	2000 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·004	8·800	0·008	0·010	0·012	0·010
		Albuminoid nitrogen - - - - - - - - - -	0·01	1·40	0·02	0·03	0·02	0·02
		Nitric nitrogen - - - - - - - - - - -	0·06	0·00	0·09	0·09	0·08	0·08
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·38	6·21	0·44	0·41	0·42	0·42
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	14·92	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·08	28·50	0·25	0·20	0·19	0·22
		Chlorine - - - - - - - - - - - - -	1·49	9·61	1·49	1·43	1·44	1·48
		Suspended solids - - - - - - - - - -	—	26·60	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	0·98	0·17	0·88	0·94	0·92	0·94
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	0·90	—	0·95	0·92	0·87	0·95
June 16, 1910.	1060 to 1	Ammoniacal nitrogen - - - - - - - - -	0·003	2·440	0·012	—	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·01	0·53	0·01	—	—	—
		Nitric nitrogen - - - - - - - - - - -	0·12	—	0·13	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·08	2·54	0·14	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	6·00	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·03	28·00	0·06	—	—	—
		Chlorine - - - - - - - - - - - - -	1·56	5·16	1·66	—	—	—
		Suspended solids - - - - - - - - - -	1·2	17·80	1·60	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	1·06	—	0·92	—	—	—

Samples drawn.	Approximate dilution of sewage with beck water.		River water just above outfall.	Sewage effluent	River water 300 yards below outfall.	River water 600 yards below outfall.	River water 2,000 yards below outfall.	River water 3,000 yards below outfall.
t. 6, 1910.	1060 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·003	1·150	0·058	0·041	0·017	—
		Albuminoid nitrogen - - - - - - - - - -	0·01	0·37	0·02	0·02	0·01	—
		Nitric nitrogen - - - - - - - - - - -	0·08	—	0·16	0·12	0·10	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	1·60	0·26	0·27	0·23	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·45	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·12	12·70	0·07	0·09	0·09	—
		Chlorine - - - - - - - - - - - - -	1·58	5·13	1·71	1·66	1·59	—
		Suspended solids - - - - - - - - - -	—	11·4	0·80	1·20	0·70	—
		Oxygen in solution when drawn - - - - - - -	1·03	—	0·98	0·98	1·12	—
		Oxygen in solution when analysed, *i.e.*, after 6 days - -	1·05	0·04	0·67	0·77	0·99	—

Summary.—1. This sewage, when diluted with above 1,000 times its own volume of very clean water moving in a slow current, did not give rise to smell.

There was, however, some smell immediately against the main outfall.

2. The water was not materially deoxygenated through admixture with the sewage.

3. There were small but objectionable deposits of mud against the two chief outfalls, more particularly against that at Hungate Bridge. Except for these local deposits the river bed was not materially affected by the solid matter of the sewage.

4. There was a fair quantity of grey fungus below Pickering. It extended for a distance of about a quarter of a mile below Hungate Bridge.

At certain seasons of the year there was a considerable development of green algal growth below Pickering.

5. Trout were present in the beck both above and below Pickering.

RUGBY AND THE RIVER AVON.

Population.—21,000.
Sewerage System.—Partially separate.
Dry weather Flow.—700,000 gallons per 24 hours.
Gauged Flow of Effluent.—530,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—Septic tanks, followed by percolating filters and irrigation over land.

Total tank capacity - - - - - - - -	697,600 gallons.
Total cubic content of filters - - - - - - -	6,399 yards.
Total irrigable area of land - - - - - - -	34½ acres.

Effluent.—This is a bright liquid with a slight brownish tint. It has a clean earthy smell, and is uniformly non-putrescible upon incubation.

It contains, on the average, about 1·5 parts per 100,000 of brown, well coagulated suspended matter. It is of fairly uniform quality and composition.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	2·12
Nitric nitrogen - - - - - - -	0·51
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	1·43
Dissolved oxygen taken up from water at 65° F:	
In 48 hours - - - - - - -	0·36
In 5 days - - - - - - -	1·97

Name of Stream.—The Warwickshire Avon.

Velocity.—The flow of water in the upper reaches of the Avon is subject to variation within very wide limits, owing to the use of the river for power.

The average current velocity, as measured over a stretch of about half a mile below the outfall, was about 30 feet per minute. In very dry weather it is much more sluggish than this.

A series of gaugings made in dry weather gave the flow of the river as about 4,500,000 gallons per 24 hours. The dilution of the effluent with river water, in dry weather, is thus about 8 to 1.

Effect of Effluent Discharge.—Visits paid in August, 1908, May and August, 1909, July and September, 1910, and January, May and June, 1911.

About half a mile below the lower Rugby outfall a very small stream, called the Sow Brook, joins the Avon. This brook is rather badly polluted.

No smell was observed below the Rugby outfalls and grey growth was practically absent. There was a small deposit of mud against the upper outfall on one side of the river.

The river bed was much overgrown with reeds and rushes both above and below the effluent outfalls. At certain seasons of the year there was a great development of green algal growth below the outfalls.

Coarse fish were present in the water below the outfall.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 400 yards below outfall.	River water 800 yards below outfall.	River water 1,300 yards below outfall.	River water 3,000 yards below outfall
Aug. 31, 1908.	16 to 1	Ammoniacal nitrogen - - - - - - - - -	0·003	—	—	—	—	0·02
		Albuminoid nitrogen - - - - - - - - -	0·02	—	—	—	—	0·03
		Nitric nitrogen - - - - - - - - - -	0·21	—	—	—	—	0·35
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	—	—	—	—	0·23
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·07	—	—	—	—	0·15
		Chlorine - - - - - - - - - - - -	2·02	—	—	—	—	3·53
		Suspended solids - - - - - - - - -	0·42	—	—	—	—	0·26
		Oxygen in solution when drawn - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	0·87	—	—	—	—	0·62
May 12, 1909.	8 to 1	Ammoniacal nitrogen - - - - - - - - -	0·163	1·470	0·151	0·310	0·310	—
		Albuminoid nitrogen - - - - - - - - -	0·04	0·16	0·06	0·10	0·07	—
		Nitric nitrogen - - - - - - - - - -	0·19	0·96	0·49	0·37	0·40	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·31	1·16	0·46	0·53	0·42	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·51	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·47	1·47	0·57	0·59	0·43	—
		Chlorine - - - - - - - - - - - -	3·00	9·24	4·83	4·95	4·36	—
		Suspended solids - - - - - - - - -	0·50	1·10	—	2·10	—	—
		Oxygen in solution when drawn - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0 96	0·62	0·67	0·74	0·82	—
Aug. 20, 1909.	20 to 1	Ammoniacal nitrogen - - - - - - - - -	0·021	1·860	—	0·014	—	0·02
		Albuminoid nitrogen - - - - - - - - -	0·03	0·14	—	0·03	—	0·03
		Nitric nitrogen - - - - - - - - - -	0·15	0·10	—	0·20	—	0·22
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·46	0·90	—	0·43	—	0·44
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·73	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·22	1·61	—	0·23	—	0·21
		Chlorine - - - - - - - - - - - -	2·32	11·60	—	2·40	—	2·92
		Suspended solids - - - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when drawn - - - - - -	0·62	0·29	0·52	0·58	—	0·43
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	0·66	0·20	—	0·63	—	0·48

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 400 yards below outfall.	River water 800 yards below outfall.	River water 1,300 yards below outfall.	River water 3,000 yards below outfall.
July 5, 1910.	10 to 1	Ammoniacal nitrogen	0·028	1·630	0·059	—	—	—
		Albuminoid nitrogen	0·03	0·26	0·04	—	—	—
		Nitric nitrogen	0·13	1·36	0·19	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·26	2·00	0·30	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·27	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·12	3·03	0·25	—	—	—
		Chlorine	2·11	11·50	2·63	—	—	—
		Suspended solids	0·50	8·50	0·30	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·88	0·35	0·73	—	—	—
Sept. 28, 1910.	8 to 1	Ammoniacal nitrogen	—	—	0·194	—	—	0·021
		Albuminoid nitrogen	—	—	0·05	—	—	0·03
		Nitric nitrogen	—	—	0·16	—	—	0·40
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	—	0·38	—	—	0·31
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	—	—	0·43	—	—	0·15
		Chlorine	—	—	4·70	—	—	4·22
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	0·16	—	—	0·66
		Oxygen in solution when analysed, *i.e.*, after 1 day	—	—	0·57	—	—	0·63
Jan. 23, 1911.	8 to 1	Ammoniacal nitrogen	0·017	1·89	—	0·025	—	0·042
		Albuminoid nitrogen	0·02	0·11	—	0·02	—	0·02
		Nitric nitrogen	0·24	1·74	—	0·23	—	0·32
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	—	—	0·21	—	0·24
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·96	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·26	0·98	—	0·11	—	0·25
		Chlorine	1·79	9·28	—	1·86	—	2·11
		Suspended solids	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·31	1·16	—	1·15	—	1·16
May 15, 1911.	8 to 1	Ammoniacal nitrogen	0·009	1·880	—	0·098	0·52	—
		Albuminoid nitrogen	0·03	0·24	—	0·06	0·04	—
		Nitric nitrogen	0·10	1·26	—	0·30	0·30	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	1·21	—	0·35	0·33	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·10	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·21	2·90	—	0·55	0·41	—
		Chlorine	2·24	10·38	—	3·01	3·49	—
		Suspended solids	1·50	2·80	—	1·50	0·90	—
		Oxygen in solution when drawn	0·88	0·35	—	0·89	0·77	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·81	0·31	—	0·77	0·79	—
May 23, 1911.	8 to 1	Ammoniacal nitrogen	0·038	1·370	—	0·011	—	—
		Albuminoid nitrogen	0·04	0·22	—	0·03	—	—
		Nitric nitrogen	0·17	1·35	—	0·32	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·31	1·25	—	0·33	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·06	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·09	2·69	—	0·19	—	—
		Chlorine	2·76	12·15	—	2·94	—	—
		Suspended solids	1·50	4·20	—	1·40	—	—
		Oxygen in solution when drawn	—	—	—	0·52	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·64	0·28	—	0·79	—	—
June 2, 1911.	10 to 1	Ammoniacal nitrogen	0·013	1·180	—	0·199	—	—
		Albuminoid nitrogen	0·03	0·18	—	0·07	—	—
		Nitric nitrogen	0·07	1·52	—	0·42	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·37	1·47	—	0·64	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·29	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·21	1·33	—	—	—	—
		Chlorine	2·22	9·52	—	4·22	—	—
		Suspended solids	0·70	1·40	—	0·70	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	1·07	0·09	—	0·57	—	—

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 400 yards below outfall.	River water 800 yards below outfall.	River water 1,300 yards below outfall.	River water 3,000 yards below outfall.
June 20, 1911.	8 to 1	Ammoniacal nitrogen - - - - - - - - -	0·080	0·660	—	0·029	—	—
		Albuminoid nitrogen - - - - - - - - -	0·07	0·12	—	0·029	—	—
		Nitric nitrogen - - - - - - - - - -	0·11	1·40	—	0·12	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·30	0·99	—	0·36	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·75	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·34	2·08	—	0·32	—	—
		Chlorine - - - - - - - - - - - - -	2·80	12·40	—	3·30	—	—
		Suspended solids - - - - - - - - - -	0·60	0·70	—	0·90	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·70	0·18	—	0·38	—	—
Aug 9, 1911.	8 to 1	Oxygen in solution when drawn - - - - - -	0·30	—	0·29	0·31	—	—

Summary.—1. This effluent, when diluted with about 8 times its own volume of clean water, moving in a slow to very sluggish current, did not give rise to smell.

2. Occasionally in dry weather the admixture of the effluent caused considerable deoxygenation of the river water in the very sluggish reaches below the outfalls.

3. There was a small deposit of mud against the upper effluent outfall on one side of the river, but beyond this the bed of the river was not materially affected.

4. Only a small quantity of grey growth was observed below the outfalls, but green algal growth was abundant below the outfalls in the warmer months of the year.

5. Small coarse fish were seen below the outfall.

ST. NEOTS AND THE RIVER OUSE.

Population.—4,000.
Sewerage System.—Combined.
Dry weather Flow.—About 100,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—The sewage is partially settled in a septic tank. Total capacity of tank about 20,000 gallons.

Septic Tank Liquor.—This is a dark, turbid and foul smelling liquid, containing, on the average, about 40 parts of suspended matter per 100,000.

It is of variable composition.

	Parts per 100,000.
Ammoniacal nitrogen	6·39
Nitric nitrogen	0·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	12·95
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	15·2
In 5 days	28·5

Name of Stream.—The River Ouse.

Velocity.—The current velocity in dry weather is slow.

Below St. Neots, from the bridge to St. Neots Paper Mill weir, a distance of a mile and a quarter, the width of the river varies from about 150 to 200 feet. In the central channel the water is over 6 feet deep the whole length of the reach, and considerably deeper in places.

The dry weather flow of the Ouse at St. Neots is about 96,000,000 gallons per 24 hours. The dilution of the tank liquor with river water is thus about 960 to 1 in dry weather.

Effect of Tank Liquor Discharge.—Visits were paid in March, September and December, 1909, and June and October, 1910.

The tank liquor is discharged from a single outfall, placed in deep water in the centre of the river just under St. Neots Bridge.

Just below the outfall there was a deposit of putrid mud at the bottom of the river. This could not usually be seen, but in very dry weather when the river was low some of the mud rose to the surface and caused local smell.

A small quantity of grey algal growth was usually to be observed on the water weeds below the outfall. It extended for about 200 yards.

Coarse fish were plentiful both above and below the outfall.

Samples drawn.	Approximate dilution of Tank liquor with river water.		River water just above outfall.	Tank liquor.	River water 200 yards below outfall.	River water 800 yards below outfall.	River water 3,000 yards below outfall.
ar. 25, 1909.	2000 to 1	Ammoniacal nitrogen	0·016	2·870	0·009	0·0	0·009
		Albuminoid nitrogen	0·03	0·061	0·02	0·0	0·02
		Nitric nitrogen	0·44	—	0·25	0·3	0·35
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	3·66	0·22	0·2	0·28
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	7·25	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·31	22·87	0·15	0·27	0·25
		Chlorine	2·50	14·45	2·63	2·60	2·47
		Suspended solids	—	16·66	—	—	1·73
		Oxygen in solution when drawn	0·97	—	0·99	0·99	0·99
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·08	—	1·04	1·12	1·04
ept. 28, 1909.	1500 to 1	Ammoniacal nitrogen	0·009	3·100	0·020	0·020	0·010
		Albuminoid nitrogen	0·02	0·62	0·03	0·02	0·02
		Nitric nitrogen	0·13	—	0·15	0·13	0·14
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·29	—	0·32	0·30	0·28
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80 F°.	—	9·48	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·10	15·5	0·18	0·21	0·01
		Chlorine	2·81	5·27	2·81	2·82	2·78
		Suspended solids	—	32·30	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·78	—	0·75	0·83	0·77
ec. 14, 1909.	2000 to 1	Ammoniacal nitrogen	0·010	8·180	—	0·011	—
		Albuminoid nitrogen	0·03	2·46	—	0·03	—
		Nitric nitrogen	0·19	—	—	0·19	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·38	—	—	0·39	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	35·60	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·22	94·60	—	0·18	—
		Chlorine	1·94	21·90	—	1·92	—
		Suspended solids	—	167·0	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·18	—	—	1·14	—

Samples drawn.	Approximate dilution of Tank liquor with river water.		River water just above outfall.	Tank liquor.	River water 200 yards below outfall.	River water 800 yards below outfall.	River water 3,000 yards below outfall.
June 8, 1910.	960 to 1	Ammoniacal nitrogen	0·007	1·880	0·009	0·010	0·003
		Albuminoid nitrogen	0·03	0·81	0·03	0·03	0·04
		Nitric nitrogen	0·25	—	0·24	0·22	0·22
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·29	3·78	0·31	0·30	0·33
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	7·69	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·18	22·30	0·32	0·29	0·44
		Chlorine	2·50	7·48	2·54	2·50	2·52
		Suspended solids	0·70	13·00	1·00	0·80	0·70
		Oxygen in solution when drawn	0·79	0·00	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·80	—	0·72	0·73	0·97
Oct. 4, 1910	960 to 1	Ammoniacal nitrogen	0·009	8·80	0·007	—	—
		Albuminoid nitrogen	0·02	0·90	0·02	—	—
		Nitric nitrogen	0·19	—	0·15	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·15	6·70	0·16	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	13·81	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·07	40·60	0·06	—	—
		Chlorine	2·97	23·32	2·89	—	—
		Suspended solids	—	14·80	—	—	—
		Oxygen in solution when drawn	0·93	—	0·95	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·83	0·00	0·86	—	—

Summary.—1. This strong septic tank liquor, when diluted with about 960 times its own volume of clean water, moving in a slow current, did not give rise to smell.

2. The river water was not materially deoxygenated through admixture with the tank liquor,

3. There was a local deposit of putrefying mud at the outfall, which occasionally became objectionable by giving rise to local smell.

4. There was only a very slight development of grey algal growth below the outfall. Green algæ were plentiful in summer, both above and below the outfall.

5. Coarse fish were numerous below the outfall.

STRATFORD AND THE RIVER AVON.

Population.—8,300.
Sewerage System.—Combined
Dry weather Flow.—300,000 gallons per 24 hours.
Nature of Sewage.—Domestic with much brewery waste.
Treatment.—Septic tanks, followed by either single or double percolating filters, and with irrigation over a small area of land.

Total tank capacity	388,000 gallons.
Total cubic content of percolating filters	8381·5 yards.
Total cubic content of contact beds	1328·0 ,,
Total	9709·3 ,,
Total irrigable area of land	8 acres.

Effluent.—This is a bright liquid with a brownish tint. It has a clean earthy smell, and is uniformly non-putrescible upon incubation.

It contains, on the average, about 2·6 parts per 100,000 of brown, well coagulated suspended solids.

It is of fairly uniform quality and composition.

	Parts per 100,000.
Ammoniacal nitrogen	0·18
Nitric nitrogen	2·62
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·09
Dissolved oxygen taken up from water at 68° F.:	
In 48 hours	0·32
In 5 days	0·83

Name of Stream.—The Warwickshire Avon.

Velocity.—The current velocity of the Avon below the effluent outfall varies from fairly rapid to sluggish. On the average, it is rather sluggish. The river is about 100 feet wide, and varies from 3 to 10 feet in depth.

The average dry weather flow of the river is about 36,000,000 gallons per 24 hours, which gives a dilution to the effluent of about 120 to 1. The flow of the river is subject to great variation not only through rain, but also through the opening and closing of weir sluices.

Effect of Effluent Discharge.—Visits paid in September, 1908, May and August, 1909, May 1910, and February, 1911.

In the effluent channels and at the outfall itself there was usually a considerable quantity of grey algal growth (*Cladothrix Dichotoma*), and the same growth was also present for a hundred yards or so below the outfall on the outfall side of the river.

There was also, in summer, a considerable quantity of green algal growth to be seen close to the outfall.

These were the only sensible effects of the effluent on the river.

Coarse fish were plentiful below the outfall.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 400 yards below outfall.	River water 5,000 yards below outfall.
Sept. 5, 1908.	150 to 1	Ammoniacal nitrogen	0·024	0·700	0·023	—	—
		Albuminoid nitrogen	0·024	0·07	0·024	—	—
		Nitric nitrogen	0·43	1·91	0·38	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·24	—	0·22	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·18	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·07	0·60	0·05	—	—
		Chlorine	5·14	3·99	8·05	—	—
		Suspended solids	0·56	1·70	0·90	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·77	—	0·78	—	—
May 27, 1909.	240 to 1	Ammoniacal nitrogen	0·009	0·316	0·012	0·010	—
		Albuminoid nitrogen	0·04	0·25	0·05	0·05	—
		Nitric nitrogen	0·17	3·18	0·31	0·30	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·26	1·21	0·29	0·32	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·63	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·34	1·60	0·40	0·46	—
		Chlorine	3·27	9·14	3·67	3·84	—
		Suspended solids	0·80	6·60	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·83	0·59	0·86	0·84	—
Aug. 26, 1909.	240 to 1	Ammoniacal nitrogen	0·025	0·170	—	—	0·014
		Albuminoid nitrogen	0·03	0·05	—	—	0·03
		Nitric nitrogen	0·29	1·44	—	—	0·47
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·35	0·55	—	—	0·29
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·13	0·14	—	—	0·08
		Chlorine	5·12	10·63	—	—	4·70
		Suspended solids	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days	0·73	0·53	—	—	0·68

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 400 yards below outfall.	River water 5,000 yards below outfall.
May 4, 1910.	150 to 1	Ammoniacal nitrogen	0·003	0·33	0·008	—	—
		Albuminoid nitrogen	0·05	0·12	0·04	—	—
		Nitric nitrogen	0·19	1·50	0·29	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·40	0·86	0·29	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·71	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·50	3·35	0·39	—	—
		Chlorine	2·16	9·58	2·66	—	—
		Suspended solids	4·20	1·90	3·10	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·16	0·29	1·18	—	—
Feb. 24, 1911.	120 to 1	Ammoniacal nitrogen	0·059	0·138	0·055	—	—
		Albuminoid nitrogen	0·03	0·07	0·04	—	—
		Nitric nitrogen	0·40	2·14	0·50	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·32	0·48	0·32	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·78	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·29	0·42	0·23	—	—
		Chlorine	4·30	9·26	4·48	—	—
		Suspended solids	1·80	—	2·10	—	—
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days	1·05	—	1·01	—	—

Summary.—1. This effluent, when diluted with 120 times its own volume of fairly clean water moving in a rather sluggish current, did not give rise to smell.

2. The water was not materially deoxygenated through admixture with the effluent.

3. No offensive deposit of mud arose from the discharge of about 2·6 parts per 100,000 of suspended matter in the effluent under the above conditions.

4. Some grey growth (*Cladothrix Dichotoma*) grew locally near the outfall, but this only extended about 100 yards below the outfall on the outfall side of the river.

The admixture of effluent did not appear to cause any marked increase of green algal growth in the river.

5. Coarse fish were plentiful both above and below the outfall.

SWINDON AND THE RIVER RAY.

Population.—43,000.
Sewerage System.—Mainly partially separate.
Dry weather Flow.—1,000,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—Precipitation, settlement, double contact beds and land.

Note.—The land effluent from the sewage disposal works serving another portion of Swindon, and also the sewage from a village of about 500 persons, enters the River Ray above the main effluent outfall. All the storm water receives some treatment.

Total combined capacity of tanks		800,000 gallons.
	1909.	1910.
Primary contact beds	13,004	15,834 cube yards.
Secondary beds	9,038	9,038 ,, ,,
Total	22,042	24,872 ,, ,,
Total irrigable area		33 acres.

Effluent.—This is an opalescent liquid with a brownish tint. It has usually a slightly fishy smell. On the average it contains about 2·5 parts per 100,000 of suspended matter.

	Parts per 100,000.
Ammoniacal nitrogen	2·10
Nitric nitrogen	0·69
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80 F.	1·83
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	1·05
In 5 days	2·45

Name of Stream.—The River Ray, a branch tributary of the Thames.

Velocity.—The current velocity, as measured over a distance of 2,300 yards in dry weather, was found to be 38 feet per minute.

The width of the stream is from 12 to 18 feet and the depth from 6 inches to 4 feet.

The dry weather flow of the stream is about 1,000,000 gallons, so that the dilution of the effluent in dry weather is about 1 : 1. The flow of the river is subject to wide variation. A flow at the rate of about 32,000,000 gallons per 24 hours has been measured in wet weather.

Effect of Effluent Discharge.—Visits were paid in March, 1909, and January and May, 1910.

The river water was of poor quality above the outfall, having already received some sewage effluent.

Immediately below the outfall there was some deposit of mud and a strong development of grey algal growth extending for a distance of more than half a mile, and in many places covering the bed of the stream.

On one occasion an objectionable smell could be observed near the river for about half a mile below the outfall.

No fish were seen between the outfall and Moredon Bridge, a distance of about a mile and a quarter.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 200 yards below outfall.	River water 1,250 yards below outfall.	River water 2,300 yards below outfall.
Mar. 8, 1909	30 to 1	Ammoniacal nitrogen	0·038	1·130	0·148	0·152	0·138
		Albuminoid nitrogen	0·07	0·12	0·10	0·12	0·10
		Nitric nitrogen	0·31	2·13	0·72	0·73	1·18
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·96	0·67	1·12	1·09	1·09
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·20	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·48	1·11	0·90	0·88	0·95
		Chlorine	2·20	7·33	2·80	2·89	2·76
		Suspended solids	8·10	1·60	9·10	10·70	10·20
		Oxygen in solution when drawn	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·02	0·07	0·77	0·80	0·86
Jan. 11, 1910	8 to 1	Ammoniacal nitrogen	0·074	1·650	0·431	0·276	0·204
		Albuminoid nitrogen	0·07	0·14	0·09	0·08	0·07
		Nitric nitrogen	0·14	1·10	0·47	0·41	0·35
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·93	0·97	0·92	0·91	0·85
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·77	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·64	1·90	1·04	0·88	0·45
		Chlorine	2·26	7·66	3·82	3·25	2·94
		Suspended solids	5·10	3·50	4·70	5·40	4·40
		Oxygen in solution when drawn	0·79	0·12	0·69	0·66	0·86
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·01	0·10	0·80	0·85	0·88
May 25, 1910	1 to 1	Ammoniacal nitrogen	0·047	1·960	—	1·01	0·570
		Albuminoid nitrogen	0·07	0·39	—	0·12	0·09
		Nitric nitrogen	0·40	0·56	—	0·44	0·47
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·51	1·32	—	0·71	0·51
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	2·42	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·58	7·00	—	1·69	1·05
		Chlorine	3·62	10·06	—	5·96	5·01
		Suspended solids	2·0	2·7	—	1·7	1·1
		Oxygen in solution when drawn	1·37	0·09	—	0·59	0·90
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·29	0·07	—	0·61	1·02

Summary.—1. This effluent, when mixed with its own volume of water of poor quality gave rise on occasion to smell.

2. In warm weather the water of the river was materially deoxygenated through admixture with the effluent.

3. There was a small deposit of effluent mud just below the outfall, but beyond this the bed of the river was not seriously fouled with effluent suspended matter.

4. There was much grey algal growth below the outfall It extended for about half a mile and covered the bed of the river in places. In warm weather green algal growth commenced to be abundant a mile below the outfall.

5. Coarse fish were not present in the river between the outfall and Moredon Bridge, a mile and a quarter below the outfall.

TIVERTON AND THE RIVER EXE.

Population.—10,000.
Sewerage System.—Combined.
Dry weather Flow.—500,000 gallons per 24 hours.
Nature of Sewage.—Dilute domestic, but contains at times a considerable quantity of brewery refuse.
Treatment.—Septic tanks, followed by single contact beds or land filtration.

Total tank capacity	241,875 gallons.
Total cubic content of filters	3,405 yards.
Total irrigable area	14 acres.

Effluent.—The effluent discharged into the river during these observations was from the single contact beds. The land was seldom used at the time. The contact bed effluent was an opalescent liquid with a brownish tint. containing, on the average, some 7·5 parts per 100,000 of suspended matter. It had usually a bitter sewage smell.

Six samples out of eight putrefied on incubation.

	Parts per 100,000.
Ammoniacal nitrogen	1·36
Nitric nitrogen	0·15
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	2·52
Dissolved oxygen taken up from water at 65° F.:	
In 48 hours	2·61
In 5 days	4·37

Name of Stream.—The river Exe.

Velocity.—The mean current velocity of the river, as measured in rather wet weather, over a distance of 3,000 yards below the outfall, was found to be about 150 feet per minute; that is, it was very rapid.

In dry weather the current velocity is about 100 feet per minute.

The river averages about 100 feet in width, and varies in depth from about 15 inches to 10 feet in deep holes.

The river rises very rapidly in times of storm.

The dry weather flow of the river is about 100,000,000 gallons, hence the dry weather dilution of the effluent is about 200 to 1.

Effect of Effluent Discharge.—Visits were paid in February and November, 1909, and September, 1910.

A moderate quantity of grey algal growth could be seen on the outfall side of the river for a distance of about 250 yards. This was practically the only sign of pollution.

In warm weather green algæ were present in small quantities, both above and below the outfall. The river bed is composed of clean stones and rocks almost down to Bickleigh weir, rather more than a mile below the outfall, and trout were plentiful in the water.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent,	River water 300 yards below outfall	River water 1,000 yards below outfall.	River water 3,000 yards below outfall.	River water 6,000 yards below outfall	River water 12,000 yards below outfall	River water 18,000 yards below outfall
Feb. 24, 1909.	200 to 1	Ammoniacal nitrogen	0·003	0·900	—	0·003	0·007	—	—	—
		Albuminoid nitrogen	0·01	0·29	—	0·01	0·01	—	—	—
		Nitric nitrogen	0·09	1·52	—	0·08	0·08	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·08	1·40	—	0·07	0·09	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	3·70	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·26	9·00	—	0·28	0·24	—	—	—
		Chlorine	1·30	5·16	—	1·28	1·37	—	—	—
		Suspended solids	0·18	8·40	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·29	0·21	—	1·35	1·32	—	—	—
Nov. 2, 1909.	300 to 1	Ammoniacal nitrogen	0·003	0·410	0·004	—	0·003	0·004	0·004	0·004
		Albuminoid nitrogen	0·01	0·10	0·01	—	0·01	0·01	0·01	0·02
		Nitric nitrogen	0·11	0·31	0·09	—	0·08	0·09	0·09	0·09
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·11	0·50	0·10	—	0·08	0·09	0·08	0·11
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·80	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·09	1·07	0·11	—	0·11	0·48	0·14	0·18
		Chlorine	1·26	3·10	1·16	—	1·14	1·16	1·16	1·26
		Suspended solids	—	2·3	—	—	—	—	—	—
		Oxygen in solution when drawn	1·00	0·44	1·03	—	1·03	1·03	0·97	0·97
		Oxygen in solution when analysed, *i.e.*, after 2 days	1·09	0·16	1·12	—	1·09	1·08	1·06	1·02
Sept. 21, 1910.	200 to 1	Ammoniacal nitrogen	0·002	1·350	0·010	0·007	0·010	—	—	—
		Albuminoid nitrogen	0·01	0·21	0·03	0·01	0·04	—	—	—
		Nitric nitrogen	0·08	0·00	0·02	0·06	0·06	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·11	—	0·16	0·10	0·19	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.		2·29	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·18	5·20	0·30	0·14	0·35	—	—	—
		Chlorine	1·21	3·43	1·22	1·17	1·19	—	—	—
		Suspended solids	—	5·0	2·7	—	—	—	—	—
		Oxygen in solution when drawn	1·04	0·03	1·06	1·08	1·06	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·14	0·05	0·97	1·06	1·03	—	—	—

Summary.—1. This effluent, when diluted with about 200 times its own volume of clean water, moving in a rapid current, did not give rise to smell.

2. The water was not materially deoxygenated through admixture with the effluent.

3. There were no signs of any offensive deposits of mud below the outfall, the bed of the river being quite clean.

4. There was a moderate quantity of grey fungus below the outfall on the outfall side of the river, but the growth only extended for about 250 yards.

5. Trout were plentiful below the outfall.

WILPSHIRE AND THE SHOWLEY BROOK.

Population.—About 700.
Sewerage System.—Partially separate.
Dry weather Flow.—20,000 gallons per 24 hours.
Nature of Sewage.—Domestic, mainly slop water.
Treatment.—Settling tanks followed by streaming filters and artificial land plots.

Total tank capacity - - - - - - - - -	45,000 gallons.
Total cubic content of filters - - - - - - -	347 yards.
Total irrigable area of land - - - - - - - -	About 3,307 square yards.

Effluent.—The effluent is a brownish and slightly opalescent liquid, usually with a clean smell.

It contains on the average about 3·3 parts of suspended matter.

It is of variable quality and composition. Two samples out of eight putrefied upon incubation.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - -	0·69
Nitric nitrogen - - - - - - -	0·23
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - - - -	0·96
Dissolved oxygen taken up from water at 65°F.	
In 48 hours - - - - - - -	0·61
In 5 days - - - - - - -	1·23

Name of Stream.—The Showley Brook, a small tributary of the Ribble.

Velocity.—The mean velocity of the current, as measured in fairly dry weather over a stretch of about a mile, was about 20 feet per minute. The current is thus sluggish on the average.

The width of the brook varies from about 6 to 10 feet, and the depth from a few inches to 3 or 4 feet.

The volume of water in the brook is subject to variation within very wide limits. In perfectly dry weather a gauging gave the volume at about 120,000 gallons per 24 hours, while on another occasion, after heavy rain, the flow was found to be about 2,250,000 gallons per 24 hours, a variation in the proportion of about 1 to 19. Probably the average dry weather flow is about 200,000 gallons, and this would give a dilution of 10 to 1.

The volume of the stream increases rapidly below the outfall.

Effect of Effluent Discharge.—Visits were paid in February, June, and October, 1909, and in May, 1910. For a distance of about 100 yards below the outfall there was a considerable development of fresh grey fungus, while below this for about a mile the appearance of the stream was slightly deteriorated by pieces of old fungus and a light brown loose deposit of suspended matter.

A mile below the outfall there were no sensible signs of pollution. No nuisance from smell arose at any part of the stream.

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 800 yards below outfall.	River water 1,500 yards below outfall.	River water 2,500 yards below outfall.
b. 19, 1900	20 to 1	Ammoniacal nitrogen - - - - - - - - -	0·044	0·650	—	0 098	0·073	0·058
		Albuminoid nitrogen - - - - - - - - -	0·03	0·08	—	0·02	0·03	0·02
		Nitric nitrogen - - - - - - - - - -	0·14	0·52	—	0·19	0·14	0·21
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·16	0·37	—	0·17	0·17	0·18
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·80	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·36	0·73	—	0·09	0·23	0·19
		Chlorine - - - - - - - - - - -	2·05	3·74	—	2·02	2·05	1·96
		Suspended solids - - - - - - - - -	0·26	2·30	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 3 days - -	1·36	0·54	—	1·28	1·37	1·33
ne 23, 1909	70 to 1	Ammoniacal nitrogen - - - - - - - - -	0·107	0·467	—	0·046	—	—
		Albuminoid nitrogen - - - - - - - - -	0·03	0·06	—	0·04	—	—
		Nitric nitrogen - - - - - - - - - -	0·10	0·45	—	0·12	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·41	0·47	—	0·44	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·61	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·16	—	—	0·28	—	—
		Chlorine - - - - - - - - - - -	1·55	2·81	—	1·58	—	—
		Suspended solids - - - - - - - - -	—	3·0	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	0·86	0·35	—	0·82	—	—
t. 29, 1909	10 to 1	Ammoniacal nitrogen - - - - - - - - -	0·016	0·67	—	0·058	0·058	0·042
		Albuminoid nitrogen - - - - - - - - -	0·016	0·13	—	0·02	0·02	0·02
		Nitric nitrogen - - - - - - - - - -	0·15	0·15	—	0·13	0·13	0·13
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·19	0·41	—	0·19	0·21	0·23
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	0·76	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·15	0·50	—	0·10	0·20	0·08
		Chlorine - - - - - - - - - - -	1·46	3·15	—	1·50	1·52	1·51
		Suspended solids - - - - - - - - -	—	2·30	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	1·13	0·48	—	1·14	1·04	0·89
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	1·17	0·62	—	1·09	1·15	1·02

Samples drawn.	Approximate dilution of effluent with river water.		River water just above outfall.	Sewage effluent	River water 100 yards below outfall.	River water 800 yards below outfall.	River water 1,500 yards below outfall.	River water 2,500 yards below outfall.
May 26, 1909.	10 to 1	Ammoniacal nitrogen - - - - - - - - - -	0·005	1·210	0·216	—	—	—
		Albuminoid nitrogen - - - - - - - - - -	0·02	0·19	0·06	—	—	—
		Nitric nitrogen - - - - - - - - - - -	0·05	0·06	0·05	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	0·17	0·60	0·28	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	1·03	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·06	1·65	0·19	—	—	—
		Chlorine - - - - - - - - - - - - -	2·60	4·60	2·83	—	—	—
		Suspended solids - - - - - - - -	0·60	2·30	0·80	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 4 days - -	1·13	0·06	0·62	—	—	—

Summary.—1. This effluent, when diluted with about 10 times its own volume of clean water moving in a sluggish current, did not give rise to smell.

2. The water was not materially deoxygenated through admixture with the effluent.

3. The appearance of the brook was slightly affected for about half a mile below the outfall. There was a considerable quantity of grey fungus near the outfall, and below this some deposit on stones and twigs in the stream. In many places the stones were stained almost black.

4. Trout evidently come up the stream from the Ribble, but they were only seen at some distance below the outfall.

WYE (KENT) AND THE RIVER STOUR.

Population.—About 788.
Sewerage System.—Combined.
Dry weather Flow.—About 12,000 gallons per 24 hours.
Nature of Sewage.—Domestic.
Treatment.—None.
Crude Sewage.—The sewage is a domestic one of about average strength. The following figures of analysis, averages of nine samples, give a fair idea of its composition.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - - -	4·18
Total nitrogen (Kjeldahl) - - - - -	6·72
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - - -	10·33
Chlorine - - - - - - - -	9·53
Suspended solids - - - - - - -	27·73

Name of Stream.—The River Stour.

Velocity.—The current velocity, as measured in dry weather by current meter, was about 40 feet per minute. The current is rather slow for the most part, but there are some rather rapid sections.

The river is 30 to 40 feet wide and from 18 inches to 6 feet in depth. The rise in times of storm is fairly gradual, the flood water coming from cultivated land and also from the town of Ashford, which is several miles above Wye.

The dry weather flow of the river is about 8,000,000 gallons, hence the dilution of the sewage is about 660 to 1.

Effect of Sewage Discharge.—Visits paid in April and June, 1909, June, July, and October, 1910, and February, May, June and July, 1911

The sewage is discharged at one outfall placed at the side of the river. Just below this outfall there was a deposit of putrid mud, which in very dry weather is liable to become exposed to the air. Grey algal growth was plentiful on the green water-weeds just below the outfall; it could be traced for a distance of about 250 or 300 yards, but it was not conspicuous a hundred yards below the outfall.

Pieces of paper, corks, matches, etc., could be seen caught in the weeds for a distance of a mile below the outfall, or even farther.

These were the only material signs of pollution; except so far as the grey growth is concerned, they might be almost entirely obviated if the outfall were placed in a less unsuitable position, and if the sewage were properly screened. Green algal growth and aquatic plants were plentiful both above and below the outfall.

Coarse fish were present in the reach immediately below the outfall, but they appeared to be rather scarce.

Samples drawn.	Approximate dilution of sewage with river water.		River water just above outfall.	Sewage	River water 600 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	River water 2,500 yards below outfall.
April 1, 1909.	4620 to 1	Ammoniacal nitrogen - - - - - - - - -	0·027	7·240	0·033	0·033	0·030	—
		Albuminoid nitrogen - - - - - - - - -	0·03	0·94	0·02	0·02	0·02	—
		Nitric nitrogen - - - - - - - - - -	0·26	1·50	0·32	0·25	0·34	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·35	7·16	0·37	0·38	0·35	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	13·99	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 5° F. -	0·22	—	0·31	0·41	0·24	—
		Chlorine - - - - - - - - - - -	2·90	16·14	2·85	2·88	2·88	—
		Suspended solids - - - - - - - - -	—	37·2	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day - -	0·97	0·00	1·01	1·02	0·99	—
June 1, 1909.	660 to 1	Ammoniacal nitrogen - - - - - - - - -	0·004	3·560	—	—	0·012	—
		Albuminoid nitrogen - - - - - - - -	0·03	1·48	—	—	0·03	—
		Nitric nitrogen - - - - - - - - - -	0·10	0·60	—	—	0·12	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	11·90	—	—	0·27	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	24·97	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F. -	0·19	—	—	—	0·22	—
		Chlorine - - - - - - - - - - -	2·85	12·63	—	—	2·65	—
		Suspended solids - - - - - - - - -	—	74·00	—	—	—	—
		Oxygen in solution when drawn - - - - - - -	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 2 days - -	0·67	—	—	—	1·04	—

Samples drawn.	Approximate dilution of sewage with river water.		River water just above outfall.	Sewage	River water 600 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	River water 2,500 yards below outfall.
June 1, 1910	1000 to 1	Ammoniacal nitrogen	0·090	5·76	0·076	—	—	—
		Albuminoid nitrogen	0·03	1·30	0·04	—	—	—
		Nitric nitrogen	0·23	0·20	0·22	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·30	1·99	0·28	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	6 84	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·38	17·8	0·42	—	—	—
		Chlorine	2·78	11·34	2·76	—	—	—
		Suspended solids	0·30	15·80	0·30	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·50	—	0·78	—	—	—
July 13, 1910	660 to 1	Ammoniacal nitrogen	0·007	1·190	0·017	0·014	—	—
		Albuminoid nitrogen	0·02	0·39	0·03	0·03	—	—
		Nitric nitrogen	0·20	0·00	0·15	0·16	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	1·87	0·26	0·26	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	4·00	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·11	5·56	0·08	0·14	—	—
		Chlorine	2·88	2·31	2·83	2·82	—	—
		Suspended solids	0·60	14·4	0·90	0·40	—	—
		Oxygen in solution when drawn	0·80	0·30	0·97	1·07	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0 90	—	0·92	1·08	—	—
Oct. 4, 1910	660 to 1	Ammoniacal nitrogen	0·192	2·840	0·157	0·130	—	0·028
		Albuminoid nitrogen	0·03	0·93	0·03	0·04	—	0·07
		Nitric nitrogen	0·16	0·03	0·22	0·15	—	0·26
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·25	2·66	0·24	0·22	—	0·20
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	5·22	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·18	14·60	0·21	0·42	—	0·18
		Chlorine	3·31	7·63	3·07	3·06	—	2·89
		Suspended solids	—	26·30	—	—	—	—
		Oxygen in solution when drawn	0·70	0·09	0·66	0·80	—	0·70
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·67	0·17	0·67	0·81	—	0·76
Feb. 16, 1911	660 to 1	Ammoniacal nitrogen	0·051	4·290	0·053	—	—	—
		Albuminoid nitrogen	0·02	0·62	0·02	—	—	—
		Nitric nitrogen	0·31	1·52	0·31	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·14	4·75	0·19	—	—	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	9 82	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·31	24·00	0·39	—	—	—
		Chlorine	2·55	5·50	2·58	—	—	—
		Suspended solids	0·90	12·30	1·10	—	—	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	1·10	—	1·06	—	—	—
May 9, 1911	660 to 1	Ammoniacal nitrogen	0·102	6·160	0·112	0·110	0·085	0·066
		Albuminoid nitrogen	0·03	1·27	0·03	0·04	0·03	0·03
		Nitric nitrogen	0·18	—	0·13	0·26	0·23	0·24
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·28	7·20	0·26	0·30	0·22	0·28
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	13·80	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·43	29·70	0·36	0·31	0·24	0·30
		Chlorine	2·86	9·20	2·85	2·88	2·80	2·70
		Suspended solids	1·30	36·80	1·70	2·00	1·30	1·60
		Oxygen in solution when drawn	0·77	0·13	0·95	0·99	1·08	1·03
		Oxygen in solution when analysed, *i.e.*, after 2 days	0·79	—	0·82	0·86	0·96	0·96
June 19, 1911	660 to 1	Ammoniacal nitrogen	0·016	4·560	0·021	0·007	—	0·006
		Albuminoid nitrogen	0·03	0·98	0·05	0·04	—	0·03
		Nitric nitrogen	0·17	0·00	0·27	0·17	—	0·16
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·27	4·71	0·32	0·30	—	0·26
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	9·74	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·31	20·0	0·39	0·23	—	0·20
		Chlorine	2·70	9·20	2·65	2·70	—	2·57
		Suspended solids	0·70	8·20	1·00	0·90	—	0·90
		Oxygen in solution when drawn	0·86	0·36	0·96	1·32	—	0·98
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·88	—	0·91	1·22	—	0·93

Samples drawn.	Approximate dilution of sewage with river water.		River water just above outfall.	Sewage.	River water 600 yards below outfall.	River water 1,000 yards below outfall.	River water 2,000 yards below outfall.	River water 2,500 yards below outfall.
July 10, 1911	660 to 1	Ammoniacal nitrogen	0·056	2·080	0·052	0·075	0·008	—
		Albuminoid nitrogen	0·03	0·67	0·04	0·05	0·03	—
		Nitric nitrogen	0·10	0·00	0·14	0·09	0·13	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·34	4·57	0·28	0·30	0·31	—
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	9·20	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·40	21·5	0·61	0·60	0·20	—
		Chlorine	3·25	11·84	3·40	3·34	3·14	—
		Suspended solids	1·50	24·60	1·20	1·30	0·70	—
		Oxygen in solution when drawn	—	—	—	—	—	—
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·69	—	0·90	0·93	0·90	—

Summary.—1. This crude sewage, when diluted with about 600 or 700 times its own volume of fairly clean water moving in a rather slow current, did not give rise to smell.

2. The river water was not materially deoxygenated through admixture with the sewage.

3. There was an offensive deposit of black mud immediately below the outfall.

4. Grey algal growth was present in moderate quantity for a distance of 100 yards below the outfall. In summer time green algal growth was abundant in the shallows, both above and below the outfall.

5. Coarse fish are present below the outfall.

OBSERVATIONS ON RIVER AVON FROM RUGBY TO STRATFORD.

The Warwickshire Avon rises near Naseby in Northampton and, after flowing towards the north and west through the southern-most corner of Leicestershire, takes a southwesterly course across Warwickshire to Tewkesbury, where it joins the River Severn.

Its main tributaries are, on the north-west side from the source downwards, the Swift, the Sowe and the Arrow; on the southwest side, the Leam and the Stour.

Taken as a whole, the river may be described as a winding, sluggish stream, the water of which, owing to the muddy nature of the river bed, is usually somewhat turbid. The watershed is undulating agricultural land, with many private parks.

The river is extensively weired, mainly for private purposes, but a few old mills still remain.

Along the course of the river and its tributaries are situated the towns of Rugby, Coventry, Kenilworth, Leamington, Warwick, Stratford and Evesham; Rugby, Leamington, Warwick, Stratford and Evesham being on the main stream. It is noteworthy that, with the exception of Leamington and Warwick, these towns are all a considerable distance, say 10 miles or so, apart.

For many years the river, or, in the case of Coventry and Kenilworth, its tributaries, received the unpurified drainage from all these places, but with the growth of Rugby, Leamington, and especially of Coventry, during the last few decades, it became so seriously polluted that steps had to be taken to purify these sewages on land. As a result, the condition of the river improved very materially, notwithstanding the discharge into it of much unpurified storm sewage in wet weather.

During the last ten years (1902–1912) further steps towards complete purification have had to be taken. Rugby, Kenilworth and Stratford have adopted biological filtration, and Coventry has materially extended its area of land.

The particular interest of the Avon, from a river purification point of view, is that it is a sluggish stream which consists largely of sewage-derived water, and yet manages, in spite of this, to maintain itself, on the whole, in a fairly-satisfactory, or at least a passable, condition.

The stretch of river to which particular attention has been paid is from Dow Bridge on Watling Street, just above Rugby and the junction of the Swift, to Binton Bridge, below Stratford and the junction of the Stour.

From Rugby downwards through this stretch the proportion of sewage-derived water to clean water is never less than about 1 in 8 or 1 in 9, while from Baginton to the junction of the Sowe at Stoneleigh it rises to about 1 in 2·5, and from Stoneleigh to Milverton only falls to 1 in about 4·5.

Though the river generally is in a fair state, in certain reaches the pollution is evidently sufficient to bring the water to the verge of producing nuisance at ordinary times, so that in exceptionally dry weather or in times of storm, and especially if storms occur during dry weather, some smell does actually arise. These remarks apply to the years 1909, 1910 and 1911.

The following figures were obtained from samples drawn in the course of special tours down the Avon. They serve to show how the water, after deteriorating in quality below Rugby recovered itself by the time it had reached Ryton Bridge. After receiving the effluent from the Coventry sewage farm at Baginton, it fell off greatly again and had not fully recovered by the time it reached Warwick, where it received more sewage effluent.

Below Barford Bridge it was sufficiently pure to be beyond danger of serious deoxygenation, except perhaps on the occasions of storms following periods of dry weather.

River Avon.

Period of sampling.	Flow of river at time of sampling.		River Avon waters.										Coventry sewage farm effluents.		River Avon waters.				River Sowe water.	River Avon waters.						River Leam waters.		Leamington sewage farm effluent.	River Avon waters.				River Stour water.	River Avon waters.	
			South Kilworth bridge.	Dow bridge.	Avon Mill just above Rugby outfall.	Rugby upper outfall.	Just above Maud's weir.	Just above Newbold weir.	Rugby lower outfall.	Just above Little Lawford weir.	King's Newnham bridge.	Ryton bridge.	Coventry northern outfall.	Coventry southern outfall.	Rock Spinney.	Just above Bubbenhall Mill weir.	Cloud bridge.	Stare bridge.	Stoneleigh bridge.	Just above upper weir in Stoneleigh Park.	Just above lower weir in Stoneleigh Park.	Just above Blackdown Mill weir.	Just above Mill weir at Guy's Cliffe.	Just above Rock Mill weir, Milverton.	Portobello bridge. Just above junction of Leam.	Just above Leamington bridge.	Just below pumping station and storm overflow.	Water of small tributary which receives effluent from Leamington sewage farm.	Just above Warwick Castle.	Warwick sewage effluent outfall.	Barford Mill weir below Warwick sewage outfall.	Charlecote Park.	Just above Mill weir.	Just below Stratford effluent outfall.	Binton bridge.
		Distance in miles below Rugby upper effluent outfall.	—	—	—	—	—	1 mile	1 mile below upper outfall.	3 miles	5½ miles	13 miles	13¼ miles	14 miles	14½ miles	15¼ miles	16½ miles	18 miles	—	19·8 miles	20·1 miles	23 miles	25 miles	26 miles	26½ miles	—	—	—	29 miles	30 miles	31 miles	36 miles	—	44 miles	45½ miles
31st August to 5th September, 1908.	River low. Heavy rain storms occurred during period of sampling, and these caused storm overflows and surface water drains to come into action.	Ammoniacal nitrogen	0·005	0·003	—	—	—	—	—	0·024	0·006	—	—	—	—	—	0·147	0·098	0·042	0·048	0·056	—	—	0·222	0·134	0·011	0·230	0·170	0·131	—	0·088	0·024	—	0·023	—
		Albuminoid nitrogen	0·01	0·02	—	—	—	—	—	0·03	0·02	—	—	—	—	—	0·03	0·03	0·03	0·03	0·03	—	—	0·04	0·03	0·02	0·05	0·05	0·03	—	0·03	0·02	—	0·02	—
		Nitric nitrogen	0·34	0·21	—	—	—	—	—	0·35	0·33	—	—	—	—	—	0·36	0·37	0·26	0·36	0·31	—	—	0·42	0·42	0·27	0·46	1·64	0·22	—	0·43	0·43	—	0·38	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	0·14	0·19	—	—	—	—	—	0·23	0·23	—	—	—	—	—	0·32	0·33	0·29	0·31	0·29	—	—	0·50	0·32	0·23	0·40	0·84	0·46	—	0·30	0·24	—	0·22	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	0·10	0·07	—	—	—	—	—	0·15	0·15	—	—	—	—	—	0·50	0·49	0·12	0·19	0·10	—	—	0·50	0·44	0·08	0·61	0·00	0·18	—	0·18	0·07	—	0·05	—
		Chlorine	1·67	2·02	—	—	—	—	—	3·53	3·25	—	—	—	—	—	3·95	3·94	10·70	5·92	7·84	—	—	5·17	4·45	2·13	5·24	8·60	2·50	—	5·95	5·14	—	8·05	—
		Suspended solids	1·22	0·42	—	—	—	—	—	0·26	0·56	—	—	—	—	—	0·86	0·88	2·50	1·80	1·70	—	—	2·80	1·80	1·40	2·10	1·70	3·20	—	1·20	0·56	—	0·90	—
		Oxygen in solution when drawn	—	0·79	—	—	—	—	—	—	0·68	—	—	—	—	—	0·43	0·50	—	0·43	0·36	0·36	—	0·43	0·36	0·50	0·50	0·50	0·30	—	0·60	0·70	—	0·60	—
		Oxygen in solution when analysed, after 2 to 6 days	0·89	0·88	—	—	—	—	—	0·62	0·77	—	—	—	—	—	0·54	0·49	0·80	0·54	0·74	—	—	0·62	0·61	0·70	0·65	—	0·29	—	0·71	0·77	—	0·78	—
20th to 26th August, 1909.	Flow of river rather above normal. Showery weather	Ammoniacal nitrogen	—	—	0·021	—	—	0·014	—	0·022	—	0·009	—	—	0·949	—	—	0·165	0·014	0·339	—	—	0·394	—	0·241	—	0·034	—	—	—	0·268	0·025	0·007	—	0·014
		Albuminoid nitrogen	—	—	0·03	—	—	0·03	—	0·03	—	0·03	—	—	0·07	—	—	0·04	0·03	0·04	—	—	0·04	—	0·04	—	0·03	—	—	—	0·05	0·03	0·02	—	0·03
		Nitric nitrogen	—	—	0·15	—	—	0·20	—	0·22	—	0·13	—	—	0·23	—	—	0·40	0·30	0·31	—	—	0·37	—	0·37	—	0·17	—	—	—	0·31	0·29	0·17	—	0·47
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	—	0·46	—	—	0·43	—	0·44	—	0·35	—	—	0·52	—	—	0·47	0·34	0·46	—	—	0·53	—	0·46	—	0·33	—	—	—	0·47	0·35	0·18	—	0·29
		Dissolved oxygen taken up from water in 5 days at 65° F.	—	—	0·22	—	—	0·23	—	0·21	—	0·29	—	—	0·34	—	—	0·49	0·20	0·49	—	—	0·40	—	0·35	—	0·17	—	—	—	0·20	0·13	0·07	—	0·08
		Chlorine	—	—	2·32	—	—	2·40	—	2·92	—	3·72	—	—	5·17	—	—	4·50	8·84	6·13	—	—	6·15	—	6·32	—	2·92	—	6·17	—	5·32	5·12	1·65	—	4·70
		Suspended solids	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	0·62	—	0·52	0·58	—	0·43	—	0·66	—	—	0·32	—	—	0·39	0·80	0·39	—	—	0·49	—	0·62	—	0·54	—	0·56	—	0·47	0·71	0·70	—	0·70
		Oxygen in solution when analysed, after 1 to 4 days	—	—	0·66	—	—	0·63	—	0·48	—	0·64	—		0·45	—	—	0·54	0·85	0·54	—	—	0·51	—	0·62	—	0·53	—	—	—	0·38	0·73	0·71	—	0·68
28th to 30th September, 1910.	Dry weather, river about flow normal.	Ammoniacal nitrogen	—	—	—	—	—	0·194	—	0·021	—	0·006	—	—	1·176	1·115	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Albuminoid nitrogen	—	—	—	—	—	0·05	—	0·03	—	0·02	—	—	0·07	0·07	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Nitric nitrogen	—	—	—	—	—	0·16	—	0·40	—	0·32	—	—	0·04	0·14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	0·38	—	0·31	—	0·23	—	—	0·59	0·39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	—	—	—	—	—	0·44	—	0·15	—	0·17	—	—	0·55	0·40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Chlorine	—	—	—	—	—	4·70	—	4·22	—	5·19	—	—	8·84	8·18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Suspended solids	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Oxygen in solution when drawn	—	—	—	—	0·14	—	—	0·66	—	0·72	—	—	0·07	0·12	—	0·44	0·60	0·42	0·56	0·43	0·53	0·66	—	—	0·74	—	0·66	—	0·69	—	—	—	—
		Oxygen in solution when analysed, after 1 day	—	—	—	—	—	0·57	—	0·63	—	0·81	—		0·15	0·25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Face page 50.

OBSERVATIONS ON THE RIVER BRENT.

The River Brent, between Willesden and Hanwell, was for many years an example of what a river should not be.

At one time it gave rise to very serious nuisance, but it has now materially improved, and nuisance from smell is now much less pronounced and confined to dry weather.

Grey algal growth is plentiful all down the reach in question. Green algae, protozoa, gnat larvæ and many forms of insect life, etc., abound in the warmer months of the year, and fish are absent.

The following figures of analysis will give an idea of the chemical characteristics of the river water. They were obtained from samples drawn in November, 1910, and February, 1911.

Samples drawn.	Flow of river at times samples were drawn.		River water above Wembley Sewage Works.	River water just below Wembley Sewage Works.	River water 500 yards below Wembley Sewage Works.	River water at Perivale Church.	River water just above Ealing Northern Sewage Works.	River water just below Ealing Northern outfall.
ov. 11, 1910	River flow rather above normal.	Ammoniacal nitrogen	0·945	1·089	1·137	1·028	1·116	0·968
		Albuminoid nitrogen	0·14	0·14	0·15	0·12	0·13	0·10
		Nitric nitrogen	0·47	0·41	0·51	0·39	0·52	0·53
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	1·55	1·33	1·27	0·82	0·85	0·90
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	1·28	1·15	1·40	0·89	0·79	1·16
		Chlorine	8·84	8·66	9·16	9·88	9·86	9·90
		Suspended solids	10·7	6·7	6·2	4·5	2·6	1·3
		Oxygen in solution when drawn	0·35	0·32	0·30	0·53	0·53	0·52
		Oxygen in solution when analysed, *i.e.*, after 3 days	0·17	0·15	0·10	0·27	0·35	0·49
b. 15, 1911	River flow normal.	Ammoniacal nitrogen	1·470	1·650	1·450	1·030	1·050	1·350
		Albuminoid nitrogen	0·18	0·19	0·15	0·14	0·15	0·15
		Nitric nitrogen	1·07	1·11	0·53	0·58	0·67	0·59
		Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	1·36	1·34	1·10	0·91	0·88	0·84
		Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	—	—	—	—	—	—
		Dissolved oxygen taken up from water in 5 days at 65° F.	2·49	2·64	1·88	1·48	1·48	1·38
		Chlorine	10·62	10·62	10·76	10·76	10·70	10·62
		Suspended solids	4·00	3·50	2·90	3·90	2·40	1·70
		Oxygen in solution when drawn	0·24	0·17	0·23	0·47	0·55	0·58
		Oxygen in solution when analysed, *i.e.*, after 1 day	0·05	0·04	0·21	—	—	—

Summary.—1. This water was liable to give rise to smell in dry weather.

2. It was materially deoxygenated, although flowing in a shallow stream.

3. The river bed was considerably fouled with putrid mud.

4. Grey algal growth was plentiful, and at certain seasons of the year green algæ abounded.

5. Fish were absent.

TABLE OF BACTERIOLOGICAL ANALYSES CARRIED OUT BY MISS E. O. HARTLEY, UNDER DR. HOUSTON'S DIRECTION.

ALDERLEY EDGE.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
37. Alderley Edge. Brook water. Chance, 11 a.m. above outfall. February 25th, 1909.	12,000	100
38. Alderley Edge. Sewage effluent. Chance, 11.15 a.m. February 25th, 1909.	800,000	100,000
39. Alderley Edge. Brook water. Chance, 12.45 noon. February 25th, 1909. 5,000 feet below 38.	182,000	1,000
40. Alderley Edge. Brook water. Chance, 3 p.m. February 25th, 1909. 7,800 feet below 38.	31,000	10,000
41. Alderley Edge. Brook water. Chance, 5 p.m. February 25th, 1909, 11,400 feet below 38.	33,000	100
90. Alderley Edge. Brook water above the effluent outfall, after heavy storm. Taken 3.15 p.m. June 22nd, 1909.	19,000,000	100,000
91. Alderley Edge. Effluent—turbid. Taken 3.30 p.m. June 22nd, 1909.	34,000,000	1,000,000
92. Alderley Edge. Brook water plus effluent—turbid. Taken 4.45 p.m. June 22nd, 1909. 5,000 feet below 91.	6,000,000	10,000

Bacteriological Notes.—Assuming that Sample 39 fairly represents the mixture of brook water and effluent, then the brook water, 6,400 feet lower down (Sample 41) showed a remarkable improvement, bacteriologically, although it still contained between two and three times as many bacteria as the brook water above the effluent outfall (Sample 37).

BARNOLDSWICK.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
68. Barnoldswick. Beck water. 10.30 a.m. May 13th, 1909. Above outfall.	2,000	10
69. Barnoldswick. Sewage effluent. Bad (?) land effluent. 10.35 a.m. May 13th, 1909.	12,600,000	1,000,000
70. Barnoldswick. Beck water, 100 yards below outfall. 11 a.m. May 13th, 1909.	2,340,000	10,000
71. Barnoldswick. Beck water, one mile below outfall. 12 noon. May 13th, 1909.	167,000	1,000
72. Barnoldswick. Stocks Beck water at Horton Bridge. 1.30 p.m. May 13th, 1909.	92,000	100
73. Barnoldswick. Stocks Beck water at Gisburn Bridge. 3 p.m. May 13th, 1909.	10,000	1
99. Barnoldswick. Brook water above effluent outfall. Clear. 5 p.m. July 2nd, 1909.	17,000	100
100. Barnoldswick. Effluent. 5.5 p.m. July 2nd, 1909 - - -	5,100,000	10,000
101. Barnoldswick. Brook water plus effluent—600 feet below 100. Turbid. 5.15 p.m. July 2nd, 1909.	590,000	10,000
102. Barnoldswick. Brook water plus effluent—3,400 feet below 100. Clear. 6 p.m. July 2nd, 1909.	140,000	1,000
103. Barnoldswick. Brook water plus effluent—8,100 feet below outfall. 7.45 p.m. July 2nd, 1909.	67,000	1,000
11c. Barnoldswick. Beck water above outfall. 10.30 a.m. October 28th, 1909.	5,000	1,000
12c. Barnoldswick. Sewage effluent. 10.30 a.m. October 28th, 1909 -	1,000,000	100,000
13c. Barnoldswick. Fools Dyke Beck. 10.30 a.m. October 28th, 1909	250	10
14c. Barnoldswick. Beck water—100 yards below outfall. 10.15 a.m. October 28th, 1909.	276,000	10,000
15c. Barnoldswick. Beck water just above junction with Hell Forest Dyke. 10.40 a.m. October 28th, 1909.	139,000	1,000
16c. Barnoldswick. Hell Forest Dyke water. 11.40 a.m. October 28th. 1909.	8,000	10
17c. Barnoldswick. Beck water from pool just below Monks Bridge. 12 p.m. October 28th, 1909.	29,800	10
18c. Barnoldswick. Beck water just above bridge at Gisburn Park—4 to 5 miles below outfall. 3.45 p.m. October 28th, 1909.	7,700	10

Bacteriological Notes.—Assuming that Samples 70, 101 and 14c fairly represent the mixture of sewage and beck water the reduction in the number of bacteria lower down the beck was remarkable. It is, of course, due mainly to the inflow of clean tributary water.

BERKHAMPSTED.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C to 22°C. Counted third day.	B. coli test. Number per c.c.
45. Berkhampsted. Canal water. Clear above effluent outfall. Dry weather. Taken 12.45 p.m. April 19th, 1909.	22,000	1
46. Berkhampsted. Final effluent. Cloudy. 1 p.m. April 19th, 1909.	7,200,000	10,000
47. Berkhampsted. Canal water plus effluent—1,200 to 1,500 feet below 46. 1.45 p.m. April 19th, 1909.	192,000	10,000
48. Berkhampsted. Canal water plus effluent. Clear. 2,600 to 3,000 feet below outfall. 2.30 p.m. April 19th, 1909.	111,000	100
49. Berkhampsted. Canal water plus effluent—4,500 feet below 46. Clear. 3.15 p.m. April 19th, 1909.	91,000	10
101. Berkhampsted. Canal water above outfall. 10.15 a.m. August 9th, 1909.	13,700	10
102. Berkhampsted. Sewage effluent. Normal flow. 11.20 a.m. August 9th, 1909.	14,800,000	1,000,000
103. Berkhampsted. Canal water 450 feet below outfall. August 9th 1909.	180,000	1,000
104. Berkhampsted. Canal water, 100 yards below first bridge—1,200 to 1,500 feet below 102. 3 p.m. August 9th, 1909.	85,000	1,000
107. Berkhampsted. Canal water above effluent outfall. Cloudy. 1.15 p.m. November 11th, 1909.	5,000	10
108. Berkhampsted. Final contact effluent. Clear. 1.35 p.m. November 11th, 1909.	544,000	10,000
109. Berkhampsted. Canal water plus effluent—4,500 feet below 108. Cloudy. 3.35 p.m. November 11th, 1909.	16,000	100
174. Berkhampsted. Canal water just above outfall. 11.15 a.m. January 14th, 1910.	62,000	10
175. Berkhampsted. Sewage effluent. Secondary bed No. 11. 11.20 a.m. January 14th, 1910.	178,000	1,000
176. Berkhampsted. Canal water, 75 yards below outfall. 12.20 p.m. January 14th, 1910.	220,000	1,000
177. Berkhampsted. Canal water, 150 yards below outfall. 1.20 p.m. January 14th, 1910.	140,000	100

Bacteriological Notes.—Assuming that Sample 47 fairly represents the mixture of sewage effluent and canal water, then the reduction in the number of bacteria, and particularly *B. coli*, 3,000 to 3,300 feet lower down the canal (Sample 49), was remarkable.

BUXTON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C to 22°C. Counted third day.	B. coli test. Number per c.c.
95. Buxton. Wye water above works. Dry day. Taken 11 a.m. July 23rd, 1909.	93,000	1,000
96. Buxton. Effluent from sewage works. Chance. 3 filters at work. 11.30 a.m. July 23rd, 1909.	700,000	10,000
97. Buxton. Wye water, 50 yards below outfall. 11.15 a.m. July 23rd, 1909.	204,000	10,000
98⅛ Buxton. Wye water, half a mile below outfall. 12 noon. July 23rd, 1909.	184,000	1,000
99. Buxton. Wye water 2½ miles below sewage works. July 23rd, 1909	42,000	100
100. Buxton. Wye water at Blackwall Mill—3 miles below outfall. July 23rd, 1909.	14,000	10

Bacteriological Notes.—The results were somewhat remarkable inasmuch as the samples (99 and 100) collected 2½ and 3 miles below the outfall were less impure than the river water above the outfall (95). This is, of course, due to the accession of large quantities of clear water from the limestone.

CAMBRIDGE.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day,	B. coli test Number per c.c.
75. Cambridge. Cam water above outfall, contains storm water. 11.20 a.m. June 23rd, 1909.	342,000	1,000
74. Cambridge. Farm effluent. Dry day. 11 a.m. June 23rd, 1909 -	1,200,000	10,000
76. Cambridge. Cam water, 100 yards below outfall. Compare 74. June 23rd, 1909.	328,000	10,000
77. Cambridge. Cam water half a mile below outfall (*see* 75). June 23rd, 1909.	175,000	10,000
78. Cambridge. Cam water, one mile below outfall. 4 p.m. June 23rd, 1909.	54,000	1,000

Bacteriological Notes.—The river water one mile below the outfall (Sample 78) was actually less impure than the river water above the outfall (Sample 75).

CHELMSFORD.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
104. Chelmsford. River water above effluent outfall. Clear. No deposit or fungus. 12.45 p.m. November 8th, 1909.	2,800	10
105. Chelmsford. General effluent. Much detached fungus. 1.15 p.m. November 8th, 1909.	4,900,000	1,000,000
106. Chelmsford. River water plus effluent at lowest point on river of previous samples. Clear, but a good deal of fine suspended matter. 5,400 feet below 105. 4.30 p.m. November 8th, 1909.	2,390	100

Bacteriological Notes.—On this occasion, when the river was high, and when road water from Chelmsford was gaining access to it higher up, the river water contained fewer bacteria 5,400 feet below the outfall than above it, but ten times as many coli.

CONSETT.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
90. Consett. Derwent water above outfall. 12.20 noon. July 1st, 1909.	6,000	1
91. Consett. Farm effluent. 12.30 noon. July 1st, 1909 - - -	5,500,000	100
92. Consett. Derwent water 50 yards below outfall. 12.40 noon. July 1st, 1909.	52,000	10
93. Consett. Derwent water ¼ mile below outfall. 1.30 p.m. July 1st, 1909.	74,000	10
94. Consett. Derwent water at Shotley weir—¾ mile below 91. 2.15 p.m. July 1st, 1909.	48,000	10

Bacteriological Notes.—Here the river water ¾ mile below the outfall contained 8 times as many bacteria as above it.

COVENTRY.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
75. Coventry. River Avon water above effluent outfall. Dry day following long period of dry weather. Clear. 1.30 p.m. May 13th, 1909.	24,000	10
76. Coventry. Effluent from land. Clear. 2 p.m. May 13th, 1909.	2,400,000	1,000
77. Coventry. River water plus effluent. Fairly clear. 1,800 feet below 76. 2.15 p.m. May 13th, 1909.	2,110,000	10,000
78. Coventry. River water plus effluent—3,200 feet below 76. Clear. 2.30 p.m. May 13th, 1909.	340,000	1,000
79. Coventry. River water plus effluent—6,000 feet below 76. 2.45 p.m. May 13th, 1909.	390,000	1,000
109. Coventry. Avon water, 250 yards above first outfall. August 21st, 1909.	36,000	1
110. Coventry. Sewage effluent (land) at first outfall. 11.45 a.m. August 21st, 1909.	173,000	100
111. Coventry. Avon water ½ mile below outfall. No. 2. 3,200 feet below 110. August 21st, 1909.	73,000	100

Bacteriological Notes.—Although showing considerable improvement, the river water, 6,000 feet below the outfall, contained many more bacteria and *B. coli* than above the outfall.

HALSTEAD.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
79. Halstead. Colne river water at Silk Mill in town. Chance. 11 a.m. June 24th, 1909.	4,700,000	10,000
80. Halstead. Colne water, 50 yards above outfall. 11.50 a.m. June 24th, 1909.	22,000	1,000
81. Halstead. Storm water from farm. Practically settled sewage. 12 noon. June 24th, 1909.	11,000,000	100,000
82. Halstead. Colne water ½ mile below farm. 3 p.m. June 24th, 1909	2,970,000	1,000
83. Halstead. Colne river water at railway bridge. ¾ mile below outfall. June 24th, 1909.	1,650,000	1,000

Bacteriological Notes.—The river water, even ¾ mile below the outfall, contained 1,000 *B. coli* and over 1,590,000 bacteria per c.c.

HARTLEY WINTNEY.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
119. Hartley Wintney. River water above effluent outfall. Muddy. Taken at noon. January 12th, 1910.	120,000	10
120. Hartley Wintney. Effluent. Fairly clear. 12.15 p.m. January 12th, 1910.	1,200,000	1,000
121. Hartley Wintney. River water plus effluent. Turbid. 7,290 feet below 120. 4 p.m. January 12th, 1910.	120,000	10

Bacteriological Notes.—Here the results above and below the outfall were exactly the same. The river was very high on this occasion.

HUNTINGDON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
34. Huntingdon. River water above sewer outfall. Clear. 3 p.m. March 10th, 1909.	29,000	10
35. Huntingdon. Tank liquor. 3.30 p.m. March 10th, 1909 - -	3,200,000	100,000
36. Huntingdon. River water and tank liquor, 1,600 feet below 35. Fairly clear. 4 p.m. March 10th, 1909.	140,000	100
37. Huntingdon. River water and tank liquor, below Hartford bridge, 5,200 feet below 35. Fairly clear. 4 p.m. March 10th, 1909.	70,000	100
38. Huntingdon. River water and tank liquor, 8,200 feet below 35. Fairly clear. 4.35 p.m March 10th, 1909.	63,000	100
113. Huntingdon. River water above sewage outfall. Clear. 1 p.m. December 1st, 1909.	2,200	10
114. Huntingdon. Sewage. 1.30 p.m. December 1st, 1909	14,000,000	1,000,000
115. Huntingdon. River water and sewage taken at lowest point of previous samples, 8,200 feet below 114. 4 p.m. December 1st, 1909.	94,000	100

Bacteriological Notes.—Despite the high dilution the sewage caused a serious deterioration (bacteriologically) in the quality of the river water.

KENILWORTH.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
96. Kenilworth. Finham brook water above effluent outfall. 2 p.m. June 28th, 1909.	32,000	10
97. Kenilworth. Effluent, turbid. 2.30 p.m. June 28th, 1909 - -	14,800,000	100
98. Kenilworth. Brook water plus effluent, 3,960 feet below 97. 4.30 p.m. June 28th, 1909.	44,000	100
112. Kenilworth. Finham brook water above effluent outfall. 2.30 p.m. August 21st, 1909.	23,000	10
113. Kenilworth. Sewage effluent. 3 p.m. August 21st, 1909 - -	800,000	100
114. Kenilworth. Finham brook water. Westley Bridge, 3,960 feet below 113. 4 p.m. August 21st, 1909.	42,000	10

Bacteriological Notes.—In the first set of samples the river water, 3,960 feet below the outfall, did not contain many more bacteria than above the outfall, despite the large number of microbes in the effluent.

LINCOLN.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
62. Lincoln. South Delph water above outfall. 11.10 a.m. April 29th, 1909.	4,000	100
63. Lincoln. Effluent from sewage works. Average, *see* 62. 11.15 a.m. April 29th, 1909.	3,900,000	10,000
64. Lincoln. South Delph water, 300 feet below 63. 11.45 a.m., *see* 62. April 29th, 1909.	109,000	1,000
65. Lincoln. South Delph water, 3,968 feet below outfall. 1.10 p.m. April 29th, 1909.	87,000	1,000
66. Lincoln. South Delph water, 6,600 feet below outfall. 2.30 p.m. April 29th, 1909.	45,000	1,000
67. Lincoln. South Delph water at Fog Cabin, 9,740 feet below 63. 4.30 p.m. April 29th, 1909.	21,000	100

Bacteriological Notes.—Although Sample 67 (9,740 feet below outfall) contained about 5 times as many bacteria as above the outfall it nevertheless showed a remarkable improvement over Sample 64, which was collected 300 feet below the outfall.

MALTON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
55. Malton. River water above sewer outfall. 4 p.m. May 3rd, 1909.	45,000	10
56. Malton. Crude sewage taken 4.30 p.m. May 3rd, 1909 - - -	At least 10,000,000	1,000,000
57. Malton. Mixture of river water and sewage, 1,850 feet below 56. Taken 5 p.m. May 3rd, 1909.	720,000	10
58. Malton. River water and sewage, 3,310 feet below 56. 5.30 p.m. May 3rd, 1909.	650,000	100
59. Malton. River water and sewage, 5,010 feet below 56. 6 p.m. May 3rd, 1909.	85,000	100

Bacteriological Notes.—Sample 59, collected 5,010 feet below the outfall, contained less than twice as many bacteria as above the outfall, and contained considerably fewer microbes than Sample 57, which was collected 1,850 feet below the outfall.

MIDDLETON-IN-TEESDALE.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
42. Middleton-in-Teesdale. Tees water above outfall. Chance. 12.30 noon. March 3rd, 1909.	170	plus 10 c.c.
43. Middleton-in-Teesdale. Sewage effluent. 12.30 noon. March 3rd, 1909.	4,400,000	10,000
44. Middleton-in-Teesdale. Tees water 150 feet below outfall. March 3rd, 1909.	77,800	1,000
45. Middleton-in-Teesdale. Tees water, 1,000 feet below outfall. 1.10 p.m. March 3rd, 1909.	3,100	10
46. Middleton-in-Teesdale. Tees water, 3,800 feet below outfall. 2.10 p.m. March 3rd, 1909.	420	10
87. Middleton-in-Teesdale. Tees water above effluent outfall. 9.30 a.m. June 4th, 1909.	1,330	plus 10 c.c.
88. Middleton-in-Teesdale. Stoddart filter effluent. 9.35 a.m. June 4th, 1909.	14,400,000	100,000
89. Middleton-in-Teesdale. River water, 3,800 feet below 88. 10.15 a.m. June 4th, 1909.	7,000	1

Bacteriological Notes.—The river water, although not reverting to its original state of purity, improved greatly some distance below the outfall.

NUNEATON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
65. Nuneaton. River Anker water above effluent outfall. Some fibrous sediment. 1.35 p.m. May 6th, 1909.	26,000	1
66. Nuneaton. Effluent. Taken 1.45 p.m. May 6th, 1909 - -	2,800,000	10,000
67. Nuneaton. River water plus effluent, 11,000 feet below 66. 2.45 p.m. May 6th, 1909.	106,000	1,000
68. Nuneaton. River water plus effluent, 4,000 feet below 66. 3.15 p.m. May 6th, 1909.	142,000	1,000
69. Nuneaton. River water plus effluent. Clear, 5,300 feet below 66. 3.45 p.m. May 6th, 1909.	254,000	1,000
170. Nuneaton. River Anker water 40 yards above outfall. 11.30 a.m. January 13th, 1910.	91,000	1,000
171. Nuneaton. Sewage effluent. Contact beds and land. 11.40 a.m. January 13th, 1910.	1,600,000	10,000
172. Nuneaton. River Anker water, 1,000 feet below northern outfall. 12.20 noon. January 13th, 1910.	149,000	1,000
173. Nuneaton. River Anker water, 4,000 feet below outfall. January 13th, 1910.	98,000	1,000

Bacteriological Notes.—In the first set of samples the river water, 5,300 feet below the outfall, yielded very unsatisfactory results. In the second set of samples the river water, *per se*, was so impure that it is difficult to draw any useful conclusions.

OLLERTON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C to 22°C. Counted third day.	B. coli test. Number per c.c.
50. Ollerton. River water above sewer outfall. Clear. 3.15 p.m. April 22nd, 1909.	32,000	10
51. Ollerton. Sewage, very dilute with river water. 3.30 p.m. April 22nd, 1909.	19,200,000	10,000
52. Ollerton. River water plus sewage, 800 feet below 51. Clear. 3.50 p.m. April 22nd, 1909.	117,000	100
53. Ollerton. River water plus sewage, 2,900 feet below 51. Clear. 4.15 p.m. April 22nd, 1909.	44,000	100
54. Ollerton. River water plus sewage, 6,500 feet below 51. Very clear. 4.45 p.m. April 22nd, 1909.	39,000	100
110. Ollerton. River Maun water above sewage outfall. Rather cloudy. 3.30 p.m. November 16th, 1909.	119,000	100
111. Ollerton. Crude sewage. 3.38 p.m. November 16th, 1909.	13,800,000	100,000
112. Ollerton. River water plus effluent, 6,800 feet below 111. 4.35 p.m. November 16th, 1909.	101,000	1,000

Bacteriological Notes.—In the first set of samples the river water, 6,800 feet below the sewage outfall, contained about the same number of bacteria as the river water above the outfall. In the second set of samples the river water below the outfall actually contained fewer bacteria than above it.

PICKERING.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day,	B. coli test. Number per c.c.
60. Pickering. Beck water taken above sewage pollution. Very clear. 9.30 a.m. May 4th, 1909.	2,000	1
61. Pickering. Crude sewage. 10.30 a.m. May 4th, 1909 - - -	64,000,000	1,000,000
62. Pickering. River water plus sewage, 1,800 feet below 61. Clear. 11 a.m. May 4th, 1909.	1,150,000	100
63. Pickering. River water plus sewage. 11.30 a.m. May 4th, 1909 -	604,000	100
64. Pickering. River water plus sewage, 6,000 feet below 61. May 4th, 1909.	432,000	10
84. Pickering. Beck water above Pickering, river rather swollen. 10.45 a.m. June 10th, 1909	78,000	1
85. Pickering. Sewage at Hungate Bridge. 11.45 a.m. June 29th, 1909	70,000,000	100,000
86. Pickering. Beck water at Gas Works, 900 feet below last sewer. 12 noon. June 29th, 1909.	410,000	100
87. Pickering. Beck water at Low Mill weir, 1,800 feet below 85. 2.10 p.m. June 29th, 1909.	308,000	100
88. Pickering. Beck water at first weir below town, 6,000 below 85 (*see* 84.) 12.30 noon. June 29th, 1909.	301,000	100
89. Pickering. Beck Water 3 miles below Pickering. 3.15 p.m. June 29th, 1909.	251,000	100

Bacteriological Notes.—Despite the high dilution the sewage caused a serious deterioration (bacteriologically) in the quality of the river water.

RUGBY.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
70. Rugby. River Avon water above effluent outfall. 3.30 p.m. May 12th, 1909.	110	10
71. Rugby. Percolating filter effluent. 4 p.m. May 12th, 1909 - -	62,000	1,000
72. Rugby. River water plus effluent, 1,100 feet below 71. 4.30 p.m. May 12th, 1909.	14,000	1,000
73. Rugby. River water plus effluent, 2,500 feet below 71. 4.45 p.m. May 12th, 1909.	13,000	100
74. Rugby. River water plus effluent, 3,900 feet below 71. 5 p.m. May 12th, 1909.	18,000	100
105. Rugby. Avon water at old mill above outfall. 10.15 a.m. August 20th, 1909.	19,000	100
106. Rugby. Sewage effluent, mixture of both effluents. 11 a.m. August 20th, 1909.	500,000	1,000
107. Rugby. Avon water, 2,500 feet below 106. 1.30 p.m. August 20th, 1909.	22,000	10
108. Rugby. Avon water, Little Lawford, 9,800 feet below 106. 5.30 p.m. August 20th, 1909.	32,000	1

Bacteriological Notes.—In the first set of samples the filter effluent caused a considerable increase in the number of bacteria in the river water, even 2,500 feet below the outfall. In the second set of samples the comparable sample of river water yielded practically the same results as the river water above the outfall.

ST. NEOTS.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
57. St. Neots. Ouse water. Chance. River contains storm water. 10.55 a.m. March 25th, 1909.	17,400	1
58. St. Neots. Septic tank liquor. 11.20 a.m. March 25th, 1909- -	1,360,000	100,000
59. St. Neots. Ouse water, 100 yards below outfall. March 25th, 1909 -	23,000	1
60. St. Neots. Ouse water half a mile below outfall. 2 p.m. March 25th, 1909.	18,000	10
61. St. Neots. Ouse water, at Paper Mill sluice. 4 p.m. March 25th, 1909.	37,000	1,000
116. St. Neots. River water above sewer outfall. 2.15 p.m. December 14th, 1909.	16,000	10
117. St. Neots. Septic tank liquor. Septic looking. 2.30 p.m. December 14th, 1909.	195,000,000	1,000,000
118. St. Neots. River water plus sewage, 3,600 feet below 117. 4 p.m. December 14th, 1909.	18,000	10

Bacteriological Notes.—In the first set of samples, the river water, only 100 yards below the outfall, yielded nearly the same results as the river water above the outfall. Similarly, in the second set of samples, the river water, 3,600 feet below the outfall, yielded nearly the same results as the river water above the sewage outfall.

STRATFORD-ON-AVON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
80. Stratford. River Avon water above effluent outfall. Clear. 1.25 p.m. May 27th, 1909	1,870	1
81. Stratford Percolating filter plus land effluent. 1.45 p.m. May 27th, 1909	5,400,000	100,000
82. Stratford. River water plus effluent, 300 feet below 81. Clear. 2 p.m. May 27th, 1909.	16,000	100
83. Stratford. River water plus effluent, 1,300 feet below 81. Clear. 2.20 p.m. May 27th, 1909.	14,000	100
126. Stratford. Sewage effluent at outfall. 12.15 noon. August 26th, 1909.	1,400,000	10,000

Bacteriological Notes.—Even 1,300 feet below the outfall the river water showed distinct signs (bacteriologically) of contamination.

SWINDON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
29. Swindon. River Ray water, above effluent outfall, river in flood, dry day following snow and sleet. Turbid. 3 p.m. March 8th, 1909.	530,000	100
30. Swindon. General effluent. Clear. 2.30 p,m. - - - - -	2,600,000	10,000
31. Swindon. River water plus effluent on mixing. Turbid. 1,000 feet below outfall. 3.15 p.m. March 8th, 1909.	830,000	1,000
32. Swindon. River water plus effluent, 4,500 feet below 30. Cloudy, 3.45 p.m. March 8th, 1909.	720,000	1,000
33. Swindon. River water plus effluent taken at junction small stream, 5,600 feet below 30. A tinge of fluorescence in this sample. 4 p.m. March 8th, 1909.	510,000	1,000
164. Swindon. River water above outfall. River in flood. 11.45 a.m. January 11th, 1910.	68,000	1,000
165. Swindon. Sewage effluent, contact bed and land effluent. 12 noon. January 11th, 1910.	10,300,000	100,000
166. Swindon. River water, 300 feet below outfall. 12.10 p.m. January 11th, 1910.	1,260,000	1,000
167. Swindon. River water, 2,640 feet below outfall. 1.15 p.m. January 11th, 1910.	240,000	1,000
168. Swindon. Water of clear side stream. 1,20 p.m. January 11th, 1910.	54,000	10
169. Swindon. River water, 5,280 feet below outfall - - - -	330,000	10,000

Bacteriological Notes.—In the first set of samples, Sample 33 (5,600 feet below outfall) actually contained fewer bacteria (although more *B. coli*) than Sample 29 (river water above outfall.) In the second set of samples, Sample 167 (2,640 feet below outfall) contained far fewer bacteria than Sample 166 (300 feet below outfall).

TIVERTON.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
25. Tiverton. River water above outfall. Clear. 4.5 p.m. February 24th, 1909.	1,130	100
26. Tiverton. General effluent, land only. Cloudy. 4.15 p.m. February 24th, 1909.	5,500,000	At least 100,000
27. Tiverton. River water plus effluent taken at Black Bridge, 3,900 feet below 26. 5.10 p.m. February 24th, 1909.	2,870	100
28. Tiverton. Water plus effluent at Shipley Ford, 6,900 feet below 26. Quite clear. 5.45 p.m. February 24th, 1909.	3,070	100
128. Tiverton. Exe water, 100 yards above outfall. 1.40 p.m. November 2nd, 1909.	2,600	10
129. Tiverton. Sewage effluent taken at outfall. 1.50 p.m. November 2nd, 1909.	670,000	1,000
130. Tiverton. Exe water 300 yards below outfall. November 2nd, 1909	3,200	100
131. Tiverton. Exe water 1 mile below outfall. 2.45 p.m. November 2nd, 1909.	1,730	1,000
132. Tiverton. Exe water at Ford, 2 miles below Beckleigh. November 2nd, 1909.	4,200	10
133. Tiverton. Exe water at mill near Thorverton, 7 or 8 miles below outfall. 12 noon. November 3rd, 1909.	5,400	100
134. Tiverton. Exe water at end of by-pass from Thorverton Mill lead. Contains some sewage effluent. November 3rd, 1909.	21,000	10
135. Tiverton. Exe water at Bamford about 2 or 3 miles above Pynes. 2 p.m. November 3rd, 1909.	3,500	10

Bacteriological Notes.—In neither set of samples did the effluent result in any very serious deterioration (bacteriologically) of the river water.

WILPSHIRE.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
93. Wilpshire. Stream water above effluent outfall. 11.50 a.m. June 23rd, 1909.	107,000	100
94. Wilpshire. Effluent. Noon. June 23rd, 1909 - - - -	1,300,000	1,000
95. Wilpshire. Stream water plus effluent. Clear, 4,700 feet below 94. 1.15 p.m. June 23rd, 1909.	113,000	100
20*c*. Wilpshire. Stream above sewage outfall, at bend, bright and clear. 9.10 a.m. October 29th, 1909.	5,300	10
21*c*. Wilpshire. Sewage effluent, bright and clear, slight earthy smell. 9.15 a.m. October 29th, 1909.	230,000	100
22*c*. Wilpshire. At Chicken House, 2,900 feet below outfall. Slightly opalescent. Bed of river here clear. 10.20 a.m. October 29th, 1909.	7,000	10
23*c*. Wilpshire. At pool by tree near Gorse house below first farm bridge and above second, 4,000 feet below 21c. Very slightly opalescent. 11.40 a.m. October 29th, 1909.	3,400	10
24*c*. Wilpshire. At Footpath Bridge below farm house, 6,400 feet below outfall, few fine solids. Bed of stream in good condition. 12.30 noon. October 29th, 1909.	2,800	100

Bacteriological Notes.—In the first set of samples, there was not very much difference between the river water above the outfall and 4,700 feet below the outfall. In the second set of samples, the number of bacteria was actually less in samples collected, 4,700 and 6,400 feet, respectively, below the outfall than in a sample collected above the outfall.

WYE.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C. to 22°C. Counted third day.	B. coli test. Number per c.c.
39. Wye. River water above sewage outfall. Chance sample. 1.40 p.m. April 1st, 1909.	82,000	100
40. Wye. Sewage. Cloudy. Brown colour. 2.30 p.m. April 1st, 1909	21,100,000	100,000
41. Wye. River water plus sewage on mixing, 1,750 feet below 40. 2.50 p.m. April 1st, 1909.	98,000	100
42. Wye. River water plus sewage taken at Railway Bridge, 2,950 feet below 40. 3.15 p.m. April 1st, 1909.	81,000	100
43. Wye. River water plus sewage, 5,050 feet below 40. Clear. 3.30 p.m. April 1st, 1909.	70,000	100
44. Wye. River water plus sewage, 5,850 feet below 40. 3.30 p.m. April 1st, 1909.	67,000	100
84. Wye. River water above sewer outfall. Clear. Very dry weather. 2.30 p.m. June 1st, 1909.	8,000	10
85. Wye. Crude sewage. 2.45 p.m. June 1st, 1909 - - - -	77,400,000	1,000,000
86. Wye. River water plus sewage. Clear, 5,850 feet below 85. 4.25 p.m. June 1st, 1909.	26,000	1,000

Bacteriological Notes.—In the first set of samples, the river water, 5,850 feet below the outfall, contained fewer bacteria than the river water above the outfall. This was not the case in the second set of samples, but the number of bacteria, 5,850 feet below the outfall, was not as great as might have been anticipated from so foul a sewage contamination, even taking into account the considerable degree of dilution.

STONELEIGH.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C to 22°C. Counted third day.	B. coli test. Number per c.c.
115. Stoneleigh. Avon water at Stan Bridge. Compare with 111. 11 a.m. August 23rd, 1909.	31,000	10
116. Stoneleigh. Avon water at Stoneleigh Mill. 12 noon. August 23rd 1909.	21,000	10
117. Stoneleigh. Avon water, Lord Leigh's upper weir. 1 p.m. August 23rd, 1909.	17,000	10

WARWICK.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C to 22°C. Counted third day.	B. coli test. Number per c.c.
118. Warwick. Avon water at Guy's Cliffe. 12 noon. August 24th, 1909.	1,360	100
119. Warwick. Avon water at Portobello Bridge. 12.45 p.m. August 24th, 1909.	8,200	100
120. Warwick. Leam water just above junction with the Avon. 1 p.m. August 24th, 1909.	48,000	100
121. Warwick. Avon water at Grammar School. 2 p.m. August 24th, 1909.	19,000	1,000
122. Warwick. Avon water below Warwick effluent outfall. 12.15 p.m. August 24th, 1909.	22,000	1,000

BARFORD.

Description of Sample.	Number of bacteria per c.c. Gel. at 20° C to 22° C. Counted third day.	B. coli test. Number per c.c.
123. Barford. Avon water just above Barford weir. 1 p.m. August 25th, 1909.	6,100	100

CHARLECOTE.

124. Charlecote. Avon water in front of house. 2.15 p.m. August 25th, 1909.	2,500	10

Taking into account the fact that something like one-eighth of the volume of the Avon water at this point is sewage derived, the water is remarkably good bacteriologically.

MILCOTE.

Description of Sample.	Number of bacteria per c.c. Gel. at 20°C to 22°C. Counted third day.	B. coli test. Number per c.c.
125. Milcote. River water above junction with the Avon. 11. a.m. August 26th, 1909.	3,200	10

The same remark as that made in the case of Charlecote applies here also.

BINTON.

127. Binton. Avon water at Binton Bridge. 2.30 p.m. August 26th, 1909.	18,000	1,000

GENERAL BACTERIOLOGICAL NOTES.

The samples collected from each separate place were too few in number to allow of final conclusions being drawn as regards each place.

Speaking generally, the results, nevertheless, present several features of interest.

As a rule it will be found that the third sample at each place represents, approximately, the effect of the effluent on the river water after fair mixing had taken place and before any striking alteration could have taken place in the way of sedimentation or devitalisation of the bacteria.

The fourth, fifth and sixth samples represent successively the effect of sedimentation, devitalisation, etc., on the bacteria in the polluted river water.

Although the results are not uniform the improvement, generally speaking, in the river water some considerable distance below the outfall was well marked. In a few instances the river water was apparently less impure a good way below, than above, the point of discharge of the sewage effluent, but in these cases the river water above the outfall was always very impure bacteriologically.

Another point brought out by the investigation was the striking immediate effect a sewage pollution has on a river water, even when the dilution is considerable. In other words, the access of a sewage pollution to a comparatively large volume of river water alters markedly the bacterial composition of the mixed liquids, the reason being that even a well oxidised sewage effluent is apt to be much more impure bacteriologically than a river water of only average purity.

The results show that sewage pollutions have a most serious *immediate* effect bacteriologically, on the quality of river water, and that although improvement takes place fairly rapidly, the river fails, in most cases, to revert to its original state within the limits of distance which in this country would be likely to occur before fresh pollutions occurred.

COMPARISON OF BACTERIOLOGICAL AND CHEMICAL RESULTS.

PERCENTAGE REDUCTION IN EACH CASE,

Comparative Stream Samples below Outfall.	Microbes (Gel.)	Ammoniacal nitrogen.	Oxygen absorbed in 4 hours. (weak.)	Dissolved oxygen absorption in 5 days.
Alderley Edge, Nos. 39 and 40	83	31	0	29
Barnoldswick, Nos. 70 and 72	96	63	48	74
Barnoldswick, Nos. 101 and 103	89	+ 30	73	21
Barnoldswick, Nos. 13*c* and 16*c*	97	90	20	42
Berkhamsted, Nos. 47 and 49	53	68	31	44
Buxton, Nos. 97 and 100	93	92	54	38
Cambridge, Nos. 76 and 78	83	1	21	18
Consett, Nos. 93 and 94	35	86	5	+ 8
Coventry, Nos. 77 and 79	81	36	5	25
Halstead, Nos. 82 and 83	44	15	+ 4	?
Huntingdon, Nos. 36 and 38	55	7	+ 14	+ 40
Lincoln, Nos. 65 and 67	76	+ 22	0	18
Malton, Nos, 57 and 59	88	40	+ 4	25
Middleton, Nos. 45 and 46	86	+ 50	4	100
Nuneaton, Nos. 67 and 68	+ 34	+ 21	+ 10	+ 8
Nuneaton, Nos. 172 and 173	34	0	2	11
Ollerton, Nos. 52 and 54	77	37	3	+ 15
Pickering, Nos. 62 and 64	62	0	+ 3	34
Pickering, Nos. 86 and 89	38	+ 25	4	12
Rugby, Nos. 73 and 74	+ 38	0	22	27
Rugby, Nos. 107 and 108	+ 45	+ 57	+ 1	9
St. Neots, Nos. 59 and 61	+ 84	0	+ 29	+ 67
Stratford, Nos. 82 and 83	12	17	+ 11	+ 15
Swindon, Nos. 31 and 32	13	+ 3	2	2
Swindon, Nos. 166 and 167	81	36	1	15
Tiverton, Nos. 27 and 28	+ 7	+ 133	+ 35	14
Tiverton, Nos. 130 and 131	46	33	25	0
Wilpshire, Nos. 22*c* and 24*c*	60	27	+ 21	17
Wye, Nos. 41 and 44	32	9	6	23

Remarks.—Speaking broadly, the foregoing twenty-nine pairs of *comparative* river water samples, drawn at different distances below the effluent outfall (the second sample always at a greater distance than the first) showed the following results :—

	Good Agreement.	Fair Agreement.	Bad Agreement.	Total.
Comparison of reduction in :				
(1) Total bacteria and ammoniacal nitrogen	8*	10	11	29
(2) Total bacteria and " oxygen absorbed "	4	8	17	29
(3) Total bacteria and dissolved oxygen absorption	5	11	12	28

It cannot, therefore, be said that the reduction in total bacteria and the chemical purification showed any real concordance.

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* In four of the cases of good agreement, the *actual* amounts of ammoniacal nitrogen were large and in four they were small.

PART II.

PREFACE.

The main object of the extended observations on streams receiving sewage liquors or sewage effluents, which have been made for the Commission during the last four years, has been to learn how far such observations could be correlated with chemical tests applied to the waters. According to the degree of correlation would be the value of such tests as an index of the condition of the stream. The aim has thus been to work back from the water of the stream to the sewage liquor or effluent discharging into it, making certain observed conditions of the stream itself the basis of any standard or standards to be suggested.

It may be stated, in passing, that the considerations about to be brought forward with regard to the discharge of sewage, tank liquor or effluent into streams, and with regard to standards, are not concerned in safeguarding drinking-water streams, nor are they intended by us to apply to the tidal portion of a stream.

The Interim Streams Report (not published), presented by us to the Commission in March, 1910, dealt with observations on twenty-five streams, extending over nearly two years, and gave the provisional conclusions which were drawn from those observations. It was divided into four sections.

Part I. of that Report gave, for each stream, a short account of the riverside observations, together with the results of the chemical examination of the samples of sewage liquor or effluent and river water, respectively. It has now been reproduced in extended form, *i.e.*, with the later work included, in Part I. of this Appendix.

In Part II. of the Interim Report the streams were arranged roughly into four groups, according to the calculated strength or oxidizability of the sewage liquor or effluent which they received, a summary of the observations and conclusions being given at the end of each group. Although this is now superseded by the present text, it illustrates, in some detail, considerations which have been borne in mind during the extended observations on which the present recommendations to the Commission are based. Portions of it, therefore, are reproduced as an Addendum on p. 177 *et seq.*

In Part III. of the Interim Report the riverside observations were correlated with certain laboratory tests, with special regard to the question of standards. This is now superseded by Part II. of the present text, but some of it is also reproduced on p. 179 *et seq.*

Part IV. of the Interim Report consisted of the tables of bacteriological results by Dr. A. C. Houston. These have been incorporated in Part I. of this Report.

The provisional conclusions of the Interim Report have been generally sustained by our later work, which has, of course, added materially to the data available for study; and this total experience forms the basis of the detailed suggestions which, for the consideration of the Commission, we now put forward in various sections of this Appendix, in connection with a system of standard or standards for sewage liquors or for effluents.

In addition to the systematic observations on natural streams, experiments have been made with artificial streams or channels receiving diluted sewage liquors and effluents, at three different sewage works. The results of these observations are given in Part III. of this Report, p. 188, under the heading "Channel Experiments."

SECTION I

CORRELATION OF ANALYTICAL RESULTS AND OBSERVED CONDITIONS OF STREAMS, AND COMPARISON OF CERTAIN TESTS WITH ONE ANOTHER, WITH A VIEW TO THE SELECTION OF ONE OR MORE TESTS TO BE APPLIED FOR PURPOSES OF A STANDARD FOR SEWAGE EFFLUENTS.

Of the tests usually applied in the examination of sewage liquors and effluents, from domestic or mainly domestic sewage, there are, we think, seven which, for purposes of a standard, especially require detailed examination, in comparison one with another, as regards their correlation with the observed conditions of streams receiving the contaminating liquid.

They are :—

(1) Determination of ammoniacal nitrogen.
(2) Determination of albuminoid nitrogen,
(3) Determination of total organic nitrogen.
(4) Determination of oxygen absorbed from permanganate.
(5) The incubator test.
(6) Determination of dissolved oxygen absorption.
(7) Determination of suspended solids.

Other determinations in daily use are :—

(8) Oxidized (nitrous and nitric) nitrogen.
(9) Chlorine.
(10) Solids in solution.
(11) Hardness.

No. 8, oxidized nitrogen, especially when considered in relation to the amount of unoxidized nitrogen present—a recommendation made long ago by Dr. Rideal—is of great practical value when judging of the quality of an effluent; No. 9, chlorine, is frequently of great use also, in this connection; while each of the remaining two has its own significance, which may be greater or less in particular cases. We do not think, however, that these last four tests (Nos. 8 to 11) require discussion here from the point of view of a general standard for sewage effluents. In certain cases of pollution by trade waste, special standards might be required, based upon the amount of solids in solution and upon hardness.

When a sewage liquor or effluent is discharged into a clean stream, it proceeds to take up more or less of the oxygen which is in solution in the water, the quantity to be taken up depending mainly upon :—

(*a*) The respective volumes of sewage liquor or effluent and of stream water;

(*b*) The capacity of the sewage liquor or effluent, per unit volume, for taking up oxygen;

(*c*) The temperature of the water;

(*d*) In certain cases, the rate at which the stream water can reoxygenate itself.

This absorption of oxygen, which is usually an indirect and gradual absorption * brought about through the agency of bacteria, results in the ultimate oxidation of the carbonaceous matter to carbon dioxide and of the ammoniacal and other nitrogenous matter to nitrate. In the course of this absorption, if the supply of oxygen is insufficient, intermediate compounds may be formed which may give rise to nuisance. As will be shown later, the direct absorption of ammonia by water plants and the oxidation of the ammonia go on in a stream more or less concurrently with the oxidation of the carbonaceous matter.

Any test for sewage effluents, therefore, to be selected for purposes of a standard may properly be based upon the absorption of oxygen. Of the first seven tests enumerated above, Nos. 2, 3, 4, 5 and 6 all measure absorption of oxygen in one way or another, thus :—

No. 6, the determination of dissolved oxygen absorption in 5 days at 18·3° C. (65° F.) is a bacterial oxidation test. It measures the more readily oxidizable carbonaceous matter (together, sometimes, with a little of the nitrogenous matter) of the sewage liquor or effluent (*cf.* p. 78), the test reproducing to some extent the conditions obtaining in a stream.

No. 5, the incubator test, as carried out for 5 days at 27° C. (80° F.) is also a bacterial oxidation test. The source of the oxygen here, however, may be not merely dissolved oxygen, but also oxygen in combination as nitrate. In the main this test is also concerned with the oxidation of the carbonaceous matter present.

No. 4, the determination of "oxygen absorbed" from permanganate is a purely chemical test, all bacteria originally present being killed and oxygen being taken up from the permanganate added. The latter reagent (in acid solution) has no oxidizing effect on any ammonia present.

Nos. 2 and 3, the determination of albuminoid and of total organic nitrogen, are similarly purely chemical oxidation tests. They give, respectively, a measure of part or of the whole of the nitrogen existing in the form of more or less complex organic nitrogenous compounds. In their case the oxidation brought about is measured in terms, not of oxygen, but of nitrogen.

No. 1, the determination of ammoniacal nitrogen, *i.e.*, of the ammonia present in the liquid—stands in a different category from the others, seeing that the test does not involve oxidation. The ammonia which it measures constitutes, of course, a part of the oxidizable matter of a sewage effluent.

No. 7, the determination of suspended solids, also stands more or less by itself, but some of the organic matter of those solids affects, *i.e.*, is measured in, the results obtained in each of the tests, 2 to 6. This test is described in detail in Part II. (3). It is admittedly an incomplete determination, since it leaves out of account part of the colloidal matter which is present in effluents (usually in small quantity). We think, however, without having actual numerical data for the assertion, that any organic colloidal matter present in an effluent will be for the most part measured in tests 2 to 6.

The streams observations have shown that the 5 days' dissolved oxygen absorption test (taken along with the determination of suspended solids) affords a better criterion than any of the others of the polluting capacity of a sewage liquor or effluent (*cf.* Part II.–4, 5 and 6). In the present section, therefore, that test has been selected as the one with which severally to compare the others.

(1) AMMONIACAL NITROGEN.

The figure for ammoniacal nitrogen from a sewage or tank liquor gives, broadly speaking, a measure of the (now fermented) urea of the sewage; in the case of septic tank liquor it also includes ammonia from some of the more easily broken down organic nitrogen compounds, other than urea. All the ammonia of a sewage liquor is in solution.

For individual samples of sewage or tank liquor there is no definite ratio between the figure for ammoniacal nitrogen and that for either albuminoid nitrogen, total organic nitrogen, "oxygen absorbed," or dissolved oxygen absorption. In mixtures of hourly samples, as might be expected, inequalities in those ratios are materially lessened, but even then it cannot be said that definite ratios exist.

Neither is there, in the case of more or less purified sewage effluents, any definite ratio between the figure for ammoniacal nitrogen and that for albuminoid nitrogen, total organic nitrogen, "oxygen absorbed," or dissolved oxygen absorption.

The figure for ammoniacal nitrogen, given by a sewage liquor or effluent, thus stands more or less by itself.

The above statements will, we think, be acquiesced in by all who have worked on the subject, so that it seems unnecessary to enlarge upon them here.

We think also that it will be generally agreed that the most delicate chemical index of recent sewage pollution in a river water is the increase in the figure for ammoniacal nitrogen yielded by the water shortly below the outfall, as compared with the water above.

Sewage contains ammonia in comparatively large quantity, and further, the determination is one of great accuracy, especially relative accuracy in corresponding samples, so that (*e.g.*) it is permissible to draw some slight distinction between two samples of polluted river water yielding such comparatively small figures for ammoniacal nitrogen as 0·005 and 0·010 parts per 100,000 respectively.

It may thus quite reasonably be asked, why not take the determination of ammoniacal nitrogen as a standard test for measuring the polluting power of a sewage liquor or effluent? Our main reason for not recommending this is that the ammonia figure yielded by the water of a stream receiving sewage liquor or effluent does not always afford as good an index of the actually observed state of the stream as does the dissolved oxygen absorption figure. Further, the study of the oxidation of sewage liquors and filter effluents, when diluted with water in the laboratory, when passed through biological filters, and when flowing down a stream, shows that oxidation of the ammonia tends to come after oxidation of the carbonaceous matter.

The main considerations which bear on the point may now be given a little more fully as follows :—

> (1) When a mixture is made in the laboratory of sewage liquor or effluent with tap or river water, the oxidation of the carbonaceous matter present precedes that of the ammonia. This was conclusively shown by Dr. Adeney in his well-known researches on the subject.*
>
> (2) When sewage liquors are passed in reasonable quantity through biological filters, the oxidation of the carbonaceous matter and of the ammonia appears to go on concurrently, or, more correctly, both are oxidized within the limits of time that the sewage liquor remains in the filter; the conditions of a duly matured filter favour biological fermentation at one and the same time of both carbonaceous and nitrogenous matters. On the other hand, the greater the dose put on the filter beyond a certain point, the less ammonia is oxidized relatively to carbonaceous matter, *i.e.*, the oxidation of the carbonaceous matter takes precedence when the duration of contact of sewage liquor with filter material is rendered too short for efficient purification (*Cf.* Fifth Report, Appendix III., Dorking Experiments, p. 199, *et seq.*).
>
> (3) The observations made for the Commission on a number of different streams are shortly summarized in the next few paragraphs. They have shown that when a sewage effluent is discharged in reasonable quantity into a river, the *disappearance* of ammoniacal nitrogen takes place (more or less) *pari passu* with oxidation of carbonaceous matter. (*Cf.* below). That much of this ammonia is taken up directly, as food, by algæ and aquatic plants, there can be no doubt, just as *ulva latissima* takes up ammonia rapidly from

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* There may, of course, be direct absorption in certain cases, *e.g.*, through the oxidation of the sulphide of a septic tank liquor, or through the aeration of a partially de-aerated effluent.

* *Cf.* Fifth Report, App. VI., pp. 9–44.

polluted brackish water,* and certain land plants assimilate ammonia directly.† Bineau,‡ Molisch § and Miss H. Chick || have shown that certain species of fresh-water algæ can assimilate ammonia.

The results of some simple laboratory experiments which we have recently made on this point, *i.e.*, with regard to the disappearance of ammonia and nitrate from water containing aquatic plants and algæ, are given in Addendum I., p. 85. These confirm the point that certain fresh-water plants and algæ do bring about the disappearance of ammonia or nitrate, or of both, from water.

Streams Samples : First Series.

The concurrent reduction (with, it is true, a good many anomalous results, due probably to imperfect admixture of effluent and river water) in the figures for ammoniacal nitrogen and dissolved oxygen absorption in 5 days, given by twenty-nine comparative pairs of samples of polluted river waters examined up to the spring of 1910, drawn (*a*) shortly below effluent outfall ; and (*b*) a considerable distance lower down, is seen in Table I. The upper sample of each pair was drawn, so far as could be judged, far enough from the outfall to allow of proper admixture of the sewage or effluent with the water having taken place, while at those spots where the lower samples were drawn, all signs of pollution, excepting green weeds, had ceased.

It might perhaps be contended that this reduction was due less to absorption and oxidation than to the continued influx of pure ground water, especially as the Table shows, as a rule, a lesser chlorine figure in the lower sample than in the upper. But, apart from the contention that the reduction in chlorine may be to some extent due to absorption of chlorides by aquatic plants, the general percentage reduction of chlorine is less than that of ammoniacal nitrogen—a fact consistent with the decrease in ammoniacal nitrogen having been caused either by plant absorption or by nitrification, or by both together.

If, in Table I., we leave out those cases where the ammoniacal nitrogen is less than 0·010 (so as not to attempt any generalisation from quantities so small as to allow the error of experiment to be material), there remain seventeen pairs of comparative samples. In twelve of these we have concordance between the figures for ammoniacal nitrogen and dissolved oxygen absorption, *i.e.*, eleven show a reduction and one an increase in both cases. In the other five the ammoniacal nitrogen shows an increase in the lower sample, whereas in only two is there an increase in the dissolved oxygen absorption. In two of these five, however, the ammoniacal nitrogen is under 0·02, so for purposes of percentage reduction these two may also fall out. Of the remaining three, the difference in the case of one pair of samples is so slight as to be within the limits of experimental error. There thus remain only two out of the seventeen pairs where there is a marked discordance, as regards quality, given by the figures for ammoniacal nitrogen and dissolved oxygen absorption in 5 days.

Reverting to the twelve pairs of corresponding samples, of which eleven show a reduction in both tests and one an increase in both, we find that the larger reduction occurs sometimes in the one test and sometimes in the other, but that in two-thirds of the cases the larger percentage decrease is in the ammoniacal nitrogen.

These results indicate that decrease in oxidizable carbonaceous matter and decrease in ammonia go on concurrently as a polluted water finds its way down stream.

Streams Samples : Second Series.

Table II. which deals with nineteen pairs of samples drawn between April, 1910, and August, 1911, all in the warmer months of the year, is similar to Table I. The samples were corresponding ones, drawn with the aid of fluorescine. In the case of the eight marked (*), the upper sample was drawn where there were signs of pollution and the lower one where there were no signs of it. Of the remaining eleven pairs, either there were still signs of pollution where the lower sample was drawn, or both samples were drawn below signs of pollution.

A glance at the chlorine figures will show that, excepting in one or two cases, there was either no decrease in chlorine in the lower sample or there was a small increase, indicating that little or no ground water had gained access to the streams, within the distances recorded.

Only one pair of samples showed less than 0·01 part ammoniacal nitrogen, so we may consider the remaining eighteen pairs. Of these, sixteen showed a decrease in ammoniacal nitrogen in the lower as compared with the upper sample, but only nine a decrease in dissolved oxygen absorption, while there was concordance between the two tests in only seven or eight cases.

It cannot, therefore, be said that the two tests show anything like so good concordance here as in Table I. At the same time it should be borne in mind that the actual figure for dissolved oxygen absorption, yielded by the lower sample, was not large, exceeding 0·4 in only four instances.

Perhaps the only safe conclusion to be drawn from the figures for ammoniacal nitrogen and dissolved oxygen absorption in Table II. is that the polluted river waters became purer as regards ammonia in their course down stream, and that most ammonia was lost per unit length of stream when the actual ammonia content was high (the highest figure for ammoniacal nitrogen in any of the waters was about 1 part per 100,000).

Does Nitrification take place in Streams receiving Sewage Liquors and Effluents ?

As an attempt to answer this question, a study has been made of the comparative pairs of river water samples, whose analysis are partly given in Tables I. and II. The results are to be found in Addendum II., p. 89 ; this Addendum contains Table III. The average percentage reduction or increase in chlorine and in nitric (+ nitrous) nitrogen has been worked out for these samples and, after taking into consideration a number of factors which may come into play, the conclusion is drawn that nitrification does take place in the water of a polluted stream.

Self-Purification of Rivers Receiving Sewage Effluent.

What has just been said with regard to nitrification taking place in streams may be supplemented by the following note on the self-purification of rivers. A good instance of this, *i.e.*, of the disappearance in a stream of the oxidizable carbonaceous matter and of the ammonia introduced by a sewage effluent, is furnished by the Warwickshire Avon between Rugby and Coventry.

Eight samples of river water in each case were drawn (*a*) just above the highest Rugby effluent outfall * ; and (*b*) at Ryton Bridge, just above the highest Coventry effluent outfall,† there being a stretch of some 13 miles of river between the two points. The samples were not corresponding ones, but they were nearly all taken in dry weather with the flow of the river more or less normal.

Several series of careful gaugings have given the *average dry weather flow* of the river below Rugby effluent outfalls as about 5,030,000 gallons. This includes about 530,000 gallons of effluent of fair quality, giving the following figures of analysis, among others :—

Parts per 100,000.

Rugby effluent.	Average of eight sets of hourly samples (1909).	Average of seven chance samples (1909–10–11).
Ammoniacal nitrogen -	2·12	1·44
Albuminoid nitrogen - -	0·20	0·19
Nitric (plus nitrous) nitrogen	0·56	1·34
" Oxygen absorbed " from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.) - -	1·43	2·24
Dissolved oxygen taken up in 5 days at 18° C. (65° F.) -	1·97	2·24
Chlorine - - - - -	9·45	10·97
Solids in suspension - -	1·4 (5)[1]	3·1 (6)[1]

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* Letts, *Proc. Roy. Soc. Edin.*, XXIII., p. 288 (1901) ; also Fifth Report of the Commission, App. VI., p. 154, *et seq.*

† Hutchinson and Miller, *Journal of Agricultural Science*, October, 1909.

‡ Ann. de Chimie et de Phys. (1856), XLVI., p. 40.

§ *Wiener Akad. der Wiss. Mathem.-Naturw. Kl.*, 1895, CIV., p. 783.

|| *Proc. Roy. Soc.*, 1903, LXXI., p. 458.

* In May and August, 1909 ; July, 1910 ; January, May, May, June, June, 1911.

† In May and August, 1909 ; April and September, 1910 ; January, April, April, April 1911.

[1] These two figures in brackets give the number of samples examined for solids.

TABLE I.

Date.		——					Parts per 100,000.		1		2	3		4	5		6	7		8	9		10	11		12	13	14	15	16	17	18	19
							Nature of liquid entering stream.	Approximate dry weather dilution by stream.	Ammoniacal Nitrogen.		Per Cent. Reduction.	Oxygen absorbed in 4 hours from $\frac{N}{80}$ permanganate at 27° C.		Per Cent. Reduction.	Dissolved oxygen taken up in 5 days at 18° C.		Per Cent. Reduction.	Nitric (+ Nitrous‡) Nitrogen.		Per Cent. Reduction.	Chlorine.		Per Cent. Reduction.	Volatile matter in suspended solids.		Ammoniacal Nitrogen.		Oxygen absorbed in 4 hours ($\frac{N}{80}$)		Dissolved oxygen taken up in 5 days.		Nitric (+ Nitrous) Nitrogen.	
		Place and Number of sample.		Feet below outfall.		Feet below outfall.			(*a*)	(*b*)		(*a*)	(*b*)		(*a*)	(*b*)		(*a*)	(*b*)		(*a*)	(*b*)				Actual Reduction.	Reduction per 1,000 ft.†	Actual Reduction.	Reduction per 1,000 ft.†	Actual Reduction.	Reduction per 1,000 ft.†	Actual Reduction.	Reduction per 1,000 ft.†
Feb. 25th,	1909.	Alderley Edge,	No. 39	(5,280); *5,280*[*]	No. 40	(10,560)	Artificial land effluent	9 : 1	0·29	0·20	31	0·43	0·43	0	0·59	0·42	29	0·26	0·29	+ 11	3·68	3·46	6	1·7	1·4	0·09	·017	0	0	0·17	·032	+ 0·030	+ ·006
May 13th,	,,	Barnoldswick,	No. 70	(300); *12,500*	No. 72	(12,800)	Land effluent	(?) 10 : 1	0·580	0·214	63	0·578	0·303	48	1·59	0·41	74	0·080	0·112	+ 40	2·10	1·73	18	2·6	*Tr*	0·366	·029	·275	·022	1·18	·094	+ 0·032	+ ·003
July 2nd,	,,	Barnoldswick,	No. 101	(600); *12,200*	No. 103	(12,800)	Land effluent	10 : 1	0·507	0·657	+ 30	0·730	0·562	23	1·02	0·30	71	0·068	0·016	76	2·30	1·91	17	2·2	1·2 (say)§	+ 0·157	+ ·013	·168	·014	0·72	·059	0·052	·004
Oct. 28th,	,,	Barnoldswick,	No. 14c	(300); *12,500*	No. 18c	(12,800)	Land effluent	10 : 1	0·112	0·011	90	0·199	0·159	20	0·26	0·15	42	0·131	0·050	62	1·21	1·10	9	0·5	0·3 (say)	0·101	·008	·040	·003	0·11	·009	0·081	·007
April 19th,	,,	Berkhamsted,	No. 47	(1,200); *3,300*	No. 49	(4,500)	Contact effluent	4 : 1	0·576	0·185	68	0·325	0·225	31	0·71	0·40	44	0·208‡	0·220	+ 10	2·56	1·88	27	1·8 (say)	1·3 (say)	0·391	·118	·110	·033	0·31	·094	+ 0·012	+ ·004
July 23rd,	,,	Buxton,	No. 97	(150); *16,290*	No. 100	(16,440)	Percolation effluent	2½ : 1	0·063	0·005	92	0 240	0·111	54	0·13	0·08	38	0·250	0·245	2	1·61	0·98	39	0·5	*Tr*	0·058	·004	·129	·008	0·05	·003	0·005	.0003
June 23rd,	,,	Cambridge,	No. 76	(300); *4,980*	No. 78	(5,280)	Land effluent	12 : 1	0·148	0·146	1	0·311	0·247	21	0·45	0·37	18	0·300	0·304	+ 1	2·57	2·78	+ 8	0·3 (say)	0·5 (say)	0.002	·000	·064	·013	0·08	·016	+ 0·004	+ ·001
July 1st,	,,	Consett,	No. 93	(1,320); *3,680*	No. 94	(4,000)	Land effluent	80 : 1	0·028	0·005	86	0·212	0·202	5	0·13	0·14	+ 8	0·030	0·060	+ 100	1·43	1·09	24	0·3 (say)	0·4 (say)	0·023	·006	·010	·003	+ 0·01	+ ·004	+ 0·030	+ ·008
May 13th,	,,	Coventry,	No. 77	(1,800); *4,200*	No. 79	(6,000)	Land effluent	3 : 1	1·081	0·696	36	0·573	0·547	5	1·18	0·89	25	0·385‡	0·310	19	6·40	5·07	21	1·5	1·6	0·385	·092	·026	·006	0·29	·069	0·075	·018
June 24th,	,,	Halstead,	No. 82	(1,900); *1,100*	No. 83	(3,000)	Land effluent	26 : 1	0·179	0·152	15	0·444	0·463	+ 4	0·66	?	—	0·248	0·162	35	3·42	3·55	+ 4	1·0 (say)	1·0 (say)	0·027	·022	+ ·019	+ ·017	—	—	0·086	·078
March 10th,	,,	Huntingdon,	No. 36	(1,600); *6,600*	No. 38	(8,200)	Settled sewage	960 : 1	0·030	0·028	7	0·310	0·351	+ 14	0·25	0·35	+ 40	0·480	0·448	6	2·80	2·85	+ 2	1·9	2·0	0·002	·000	+ ·041	+ ·006	+ 0·10	+ ·015	0·032	·005
April 29th,	,,	Lincoln,	No. 65	(3,960); *5,780*	No. 67	(9,740)	Percolation effluent	5 : 1	0·164	0·190	+ 16	0·394	0·328	19	0·40	0·22	45	0·650	0·540	17	5·61	5·03	10	0·6 (say)	0·5 (say)	0·026	+ ·005	·066	·011	0·18	·031	0·110	·019
May 3rd,	,,	Malton,	No. 57	(1,850); *3,160*	No. 59	(5,010)	Crude sewage	400 : 1	0·010	0·006	40	0·232	0·241	+ 4	0·20	0·25	+ 25	0·120	0·148	+ 23	1·87	1·81	3	1·2 (say)	1·2 (say)	0·004	·001	+ ·009	+ ·003	+ 0·05	+ ·016	+ 0·028	+ ·009
March 4th,	,,	Middleton,	No. 45	(900); *4,380*	No. 46	(5,280)	Percolation effluent	1,400 : 1	0·006	0·009	+ 50	0·121	0·116	3	0·18	0·0	100	0·040	0·050	+ 25	0·70	0·72	+ 3	*Tr*	*Tr*	+ 0·003	·000	·005	·001	0·18	·041	+ 0·010	+ ·002
May 6th,	,,	Nuneaton,	No. 67	(1,000); *3,000*	No. 68	(4,000)	Percolation and land effluent.	2 : 1	0·224	0·272	+ 21	0·480	0·527	+ 10	0·53	0·57	+ 8	0·365	0·385	+ 6	9·75	10·18	+ 4	0·4 (say)	0·5 (say)	+ 0·048	+ ·016	+ ·047	+ ·016	+ 0·04	+ ·013	+ 0·020	+ ·007
Jan. 13th,	1910.	Nuneaton,	No. 172	(900); *4,380*	No. 173	(5,280)	Percolation and land effluent.	2 : 1	0·149	0·149	0	0·389	0·380	2	0·38	0·34	11	0·320	0·288	10	3·54	3·34	6	*Tr*	0·5 (say)	0	·000	·009	·002	0·04	·009	0·032	·007
April 22nd,	1909.	Ollerton,	No. 52	(800); *6,000*	No. 54	(6,800)	Crude sewage	1,000 : 1	0·008	0·005	37	0·240	0·233	3	0·26	0·30	+ 15	0·488‡	0·488	0	3·07	2·90	9	0·2 (say)	0·2 (say)	0·003	·000	·007	·001	+ 0·04	+ ·007	0	0
May 4th,	,,	Pickering,	No. 62	(2,500); *3,600*	No. 64	(6,100)	Crude sewage	1,060 : 1	0·008	0·008	0	0·189	0·195	+ 3	0·21	0·16	24	0·100	0·090	10	1·71	1·73	+ 1	0·5 (say)	0·5 (say)	0	·000	·006	+ ·002	0·05	·014	0·010	·003
June 29th,	,,	Pickering,	No. 86	(750); *13,370*	No. 89	(14,520)	Crude sewage	1,060 : 1	0·008	0·010	+ 20	0·439	0·420	4	0·25	0·22	12	0·090	0·084	7	1·49	1·48	1	1·2 (say)	1·0 (say)	0·002	·000	·019	·001	0·03	·002	0·006	·0005
May 12th,	,,	Rugby,	No. 73	(2,500); *1,400*	No. 74	(3,900)	Percolation and land effluent.	8 : 1	0·310	0·310	0	0·533	0·418	22	0·59	0·43	27	0·450‡	0·440	2	4·95	4·36	12	1·5	1·0 (say)	0	·000	·115	·082	0·16	·114	0·010	·007
Aug. 20th,	,,	Rugby,	No. 107	(2,640); *7,160*	No. 108	(9,800)	Percolation and land effluent.	8 : 1	0·014	0·022	+ 57	0·431	0·437	+ 1	0·23	0·21	9	0·204	0·216	+ 6	2·40	2·92	+ 22	0·3 (say)	0·3 (say)	+ 0·008	+ ·001	+ ·006	+ ·001	0·02	·003	0·012	·002
March 25th,	,,	St. Neots,	No. 59	(300); *4,980*	No. 61	(5,280)	Septic tank liquor	960 : 1	0·009	0·009	0	0·219	0·283	+ 29	0·15	0·25	+ 67	0·250	0·350	+ 40	2·63	2·47	6	0·5 (say)	0·4	0	·000	+ ·064	+ ·013	+ 0·10	+ ·020	+ 0·100	+ ·020
May 27th,	,,	Stratford,	No. 82	(300); *1,000*	No. 83	(1,300)	Percolation and land effluent.	120 : 1	0·012	0·010	17	0·295	0·317	+ 8	0·40	0·46	+ 15	0·312	0·304	3	3·67	3·84	+ 5	0·6 (say)	0·7 (say)	+ 0·002	·002	+ ·022	+ ·022	0·06	+ ·060	0·008	·008
March 8th,	,,	Swindon,	No. 31	(300); *3,700*	No. 32	(4,000)	Contact and land effluent	1 : 1	0·148	0·152	+ 3	1·117	1·090	2	0·90	0·88	2	0·74‡	0·75	+ 1	2·80	2·89	+ 3	2·8	2·5	+ 0·004	+ ·001	·027	·007	0·02	·005	+ 0·010	+ ·003
Jan. 11th,	1910.	Swindon,	No. 166	(300); *2,340*	No. 167	(2,640)	Contact and land effluent	1 : 1	0·431	0·276	36	0·917	0·911	1	1·04	0·88	15	0·468	0·408	13	3·82	3·25	15	1·1	1·0	0·155	·066	·006	·003	0·16	·069	0·060	·026
Feb. 24th,	1909.	Tiverton.	No. 27	(3,900); *2,700*	No. 28	(6,600)	Contact and land effluent	200 : 1	0·003	0·007	+ 130	0·068	0·092	+ 35	0·28	0·24	14	0·080	0·080	0	1·28	1·37	+ 7	*Tr*	*Tr*	+ 0·004	+ ·002	+ ·024	+ ·009	0·04	·015	0	0
Nov. 2nd,	,,	Tiverton,	No. 130	(1,050); *5,550*	No. 131	(6.600)	Contact and land effluent	200 : 1	0·004	0·003	25	0·103	0·077	25	0·11	0·11	0	0·090	0·080	11	1·16	1·14	2	*Tr*	*Tr*	0·001	·000	·026	·005	0	·000	0·010	·002
Oct. 29th,	,,	Wilpshire,	No. 22c	(3,300); *8,580*	No. 24c	(11,880)	Artificial land effluent	8 : 1	0·058	0·042	38	0·190	0·230	+ 21	0·12	0·10	17	0·126	0·134	+ 6	—		—	*Tr*	0·3 (say)	0·016	·002	+ ·040	+ ·005	0·02	·002	+ 0·008	+ 001
April 1st,	,,	Wye (Kent)	No. 41	(1,750); *4,100*	No. 44	(5,850)	Crude sewage	660 : 1	0·033	0·030	9	0·374	0·353	6	0·31	0·24	23	0·325	0·337	+ 4	2·85	2·88	+ 1	0·5 (say)	0·4 (say)	0·003	·000	·021	·005	0·07	·017	+ 0·012	+ ·003

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[*] The figures in italics give the distance in feet between each pair of samples. † This is not a strictly true comparison, the distances between the different pairs of corresponding samples varying materially. Still, putting aside Wilpshire, Barnoldswick, Buxton and Pickering, where the distances were from 8,500 to 13,000 feet, and Stratford, Halstead and Rugby, where they were from 1,000 to 1,400 feet, all the others were between 3,000 and 7,000 feet (mostly between 3,000 and 5,000). ‡ One or both of these pairs of samples contained a little nitrite. § The word "say" in this column means that the volatile matter in the small amount of suspended solids present was not estimated directly; the figures given are merely rough estimates, based upon those obtained by the centrifuge.

TABLE II.

Date.	—			Parts per 100,000.		1		2	3		4	5		6	7		8	9		10	11	12	13	14	15	16	17	18	19
	Place and Number of sample.	Feet below outfall.	Feet below outfall.	Nature of liquid entering stream.	Approximate dry weather dilution by stream.	Ammoniacal Nitrogen.		Per Cent. Reduction.	Oxygen absorbed in 4 hours from $\frac{N}{80}$ permanganate at 27° C.		Per Cent. Reduction.	Dissolved oxygen taken up in 5 days at 18° C. †		Per Cent. Reduction.	Nitric (+ Nitrous).‡ Nitrogen		Per Cent. Reduction.	Chlorine.		Per Cent. Reduction.	Volatile matter in suspended solids.	Ammoniacal Nitrogen.		Oxygen absorbed in 4 hours ($\frac{N}{80}$).		Dissolved oxygen taken up in 5 days.		Nitric (+ Nitrous) Nitrogen.	
						(a)	(b)		(a)	(b)		(a)	(b)		(a)	(b)		(a)	(b)			Actual Reduction.	Reduction per 1,000 ft.†	Actual Reduction.	Reduction per 1,000 ft.†	Actual Reduction.	Reduction per 1,000 ft.†	Actual Reduction.	Reduction per 1,000 ft.†
Oct. 6th. 1910.	Alderley Edge,	No. 8c (2,000) ; *5,800* (1)	No. 10c (7,800)	Artificial land effluent	9 : 1	·188	·096	49	·538	·527	2	·16	·39	+ 144	·130	·186	+ 43	3·86	3·84	0	0·7 1·0	·092	·016	·011	·002	+ ·23	+ ·040	+ ·056	+ ·010
May 30th, 1911.	*Alderley Edge,	No. 1018c (1,250) ; *6,550*	No. 1020c (7,800)	Artificial land effluent	9 : 1	·360	·162	55	·525	·487	7	0·95†	0·64	33	·185‡	·410	+ 122	5·15	4·32	16	1·4 0·7	·198	·030	·038	·006	·32	·050	+ ·225	+ ·034
Aug. 12th, 1910.	*Cambridge,	No. 241 (1,200) ; *1,050*	No. 242 (2,250)	Land effluent	12 : 1	·045	·044	2	·164	·166	+ 1	·27	·27	± 0	·448	·412	8	2·57	2·46	4	0·1 0·4	·001	·001	+ ·002	+ ·002	0	0	·036	·034
Aug. 11th ,,	Chelmsford,	No. 237 (900) ; *3,200*	No. 238 (4,100)	Land effluent	26 : 1	·314	·099	68	·389	·302	22	·23 + x	·30	?	·092	·075	18	5·01	3·92	22	0·5 0·3	·215	·067	·087	·027	(?)	(?)	·017	·005
May 3rd, 1911.	Chelmsford,	No. 1002c (900) ; *3,200*	No. 1003c (4,100)	Land effluent	26 : 1	·083	·105	+ 27	·311	·318	+ 2	·33†	·32	3	·188	·248	+ 32	3·83	4·07	+ 6	1·0 1·2	+ ·022	+ ·007	+ ·007	+ ·002	·02	·006	+ ·060	+ ·019
June 16th, 1911.	Chelmsford.	No. 1025c (900) ; *3,200*	No. 1026c (4,100)	Land effluent	26 : 1	·096	·066	31	·281	·331	+ 18	·41	·36	12	·120‡	·220	+ 83	4·15	3·55	14	0·6 0·5	·030	·009	+ ·050	+ ·016	·05	·016	+ ·100	+ ·031
July 12th, 1910.	Hartley Wintney,	No. 224 (1,500) ; *1,500*	No. 225 (3,000)	Contact and land effluent	55 : 1	·025	·026	+ 4	·338	·300	11	·14	·04	81	·108	·090	17	1·79	1·86	+ 4	0·4 0·3	+ ·001	+ ·001	·038	·025	·10	·067	·018	·012
Oct. 5th, ,,	Hartley Wintney,	No. G8 (1,500) ; *1,500*	No. G9 (3,000)	Contact and land effluent	55 : 1	·035	·029	17	·219	·227	+ 4	·06	·07	+ 17	·062	·056	10	1·83	1·89	+ 3	0·5 (say) 0·4§ (say)	·006	·004	+ ·008	+ ·005	+ ·01	+ ·002	·006	·004
Aug. 17th, ,,	*Kenilworth,	No. 245 (2,000) ; *2,500*	No. 246 (4,500)	Percolation effluent	15 : 1	·020	·012	40	·340	·307	10	·21	·17	19	·564	·600	+ 6	4·56	4·79	+ 5	0·6 0·6	·008	·003	·033	·013	·04	·016	+ ·360	+ ·144
Oct. 5th, 1910.	Malton,	No. 296 (2,000) ; *3,000*	No. 298 (5,000)	Crude sewage	400 : 1	·013	·012	8	·386	·388	± 0	·15†	·08	47	·072	·075	+ 4	1·61	1·62	+ 1	0·8 0·5	·001	0	+ ·002	+ ·001	·08	·027	+ ·003	+ ·001
Aug. 11th, 1911.	Malton,	No. 2025 (2,000) ; *3,000*	No. 2026 (5,000)	Crude sewage	400 : 1	·016	·011	31	·195	·187	4	·28	·19	32	·115	·090	22	1·72	1·73	+ 1	0·3 (say) 0·4 (say)	·005	·002	·008	+ ·003	·09	·030	·025	+ ·008
April 27th, 1910.	*Nuneaton,	No. 211 (1,000) ; *3,000*	No. 212 (4,000)	Percolation and land effluent.	3 : 1	·352	·326	7	·556	·553	± 0	·48	·54	+ 12	·500‡	·550	+ 10	6·44	6·49	+ 1	0·8 0·9	·026	·009	·003	·001	+ ·06	+ ·020	+ ·050	+ ·017
Oct. 6th, 1910	*Pickering,	No. 301 (900) ; *2,100*	No. 302 (3,000)	Crude sewage	1,060 : 1	·058	·041	30	·259	·266	+ 3	·07	·09	+ 29	·160	·120	25	1·71	1·66	3	0·6 0·7	·017	·008	+ ·007	+ ·003	+ ·02	+ ·010	·040	·019
June 8th, ,,	*St. Neots,	No. 219 (500) ; *4,000*	No. 221 (4,500)	Septic tank liquor	960 : 1	·009	·003	33	·306	·326	+ 7	·32	·44	+ 38	·240	·220	8	2·54	2·52	1	0·6 0·7	·006	·002	+ ·020	·005	+ ·12	+ ·030	·020	·005
Sept. 21st. ,,	*Tiverton,	No. 265 (750) ; *3,250*	No. 266 (4,000)	Contact and land effluent	200 : 1	·010	·007	30	·160	·104	35	·30	·14	53	·024	·064	+ 166	1·22	1·17	4	1·3 *Tr*	·003	·001	·056	·017	·16	·054	+ ·040	+ ·012
July 13th, ,,	Wye,	No. 229 (1,600) ; *1,100*	No. 230 (2,700)	Crude sewage	660 : 1	·017	·014	18	·256	·258	+ 1	·08	·14	+ 75	·152	·160	+ 5	2·83	2·82	0	0·5 0·2	·003	·003	+ ·002	+ ·002	+ ·06	+ ·055	+ ·008	+ ·007
Oct. 4th, ,,	Wye,	No. G3 (1,600) ; *1,100*	No. G4 (2,700)	Crude sewage	660 : 1	·157	·130	17	·239	·224	8	·21	·42	+ 100	·220	·154	30	3·07	3·06	0	0·7 (say) 0·4 (say)	·027	·025	·015	·014	+ ·21	+ ·191	·066	·060
May 9th, 1911.	Wye,	No. 2007 (1,600) ; *1,100*	No. 2008 (2,700)	Crude sewage	660 : 1	·112	·110	2	·257	·302	+ 18	·36	·31	14	·184‡	·275	+ 49	2·85	2·88	+ 1	1·0 1·0	·002	·002	+ ·045	+ ·041	·05	·045	+ ·091	+ ·082
June 19th, ,,	Wye,	No. 2013 (1,600) ; *1,100*	No. 2014 (2,700)	Crude sewage	660 : 1	·021	·007	33	·319	·297	7	·39†	·24	38	·275	·168	39	2·65	2·70	+ 2	0·6 0·5	·014	·013	·022	·020	·16	·145	·107	·096

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[1] The figures in italics give the distance between each pair of samples.

* In those seven cases the upper sample was drawn where there were no signs of pollution, and the lower one where there were signs of it.

† In three of the above pairs (Nos. 1,018c, 296, 2013, and corresponding samples), the dissolved oxygen absorption was estimated after 6 days, and in one pair (Nos. 1002c and 1003c) after 7 days; the figures found have therefore been reduced to five-sixths and five-sevenths respectively.

‡ One or both of these pairs of samples contained a little nitrite.

§ See note on Table I.

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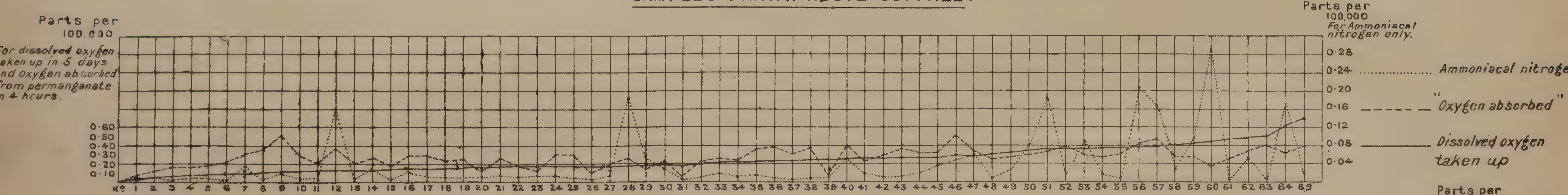
[Table II.—*To follow Table I.*

DIAGRAM A. (CORRESPONDING TO TABLE IV IN ADDENDUM III. p. 91.)

SAMPLES DRAWN ABOVE OUTFALL.



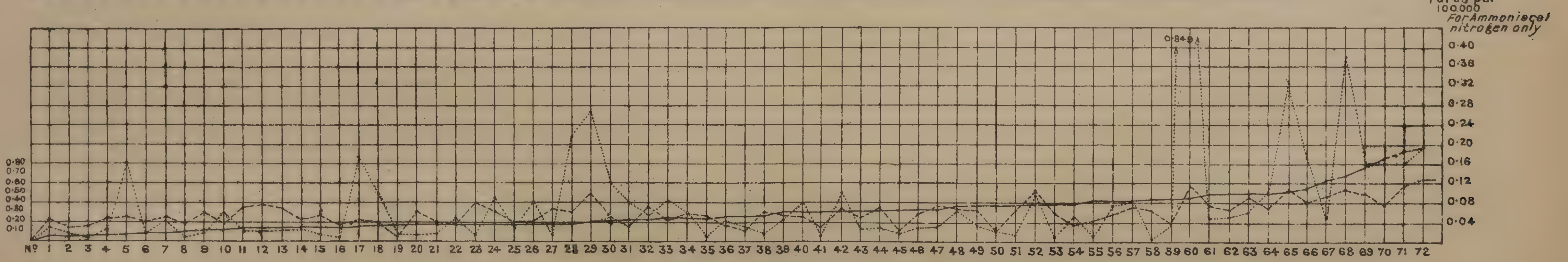


DIAGRAM B (CORRESPONDING TO TABLE V IN ADDENDUM III. p. 92.)

SAMPLES DRAWN BELOW SIGNS OF POLLUTION.

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Gaugings of the river in dry weather at Bubbenhall, below the Coventry outfalls, showed the flow of the river above the outfalls (*i.e.*, at Ryton Bridge) to be about 7,500,000 gallons.[*] The natural increase in volume of the Avon between Rugby and Ryton Bridge was, therefore, about 2,500,000 gallons.

The analysis of the eight samples of Rugby water and the eight samples of Ryton Bridge water (which were fairly even in both cases) gave the figures shewn in the following table:—

Parts per 100,000.

	Near Avon Bridge, above Rugby outfall.	Ryton Bridge, above Coventry outfall.
	Min. Max. Average.	Min. Max. Average.
Ammoniacal nitrogen - - - - - - -	(0·01 — 0·16) = 0·05	(0·00 — 0·03) = 0·01
Albuminoid nitrogen - - - - - - -	(0·02 — 0·07) = 0·04	(0·02 — 0·04) = 0·03
Nitric nitrogen - - - - - - - -	(0·10 — 0·24) = 0·15	(0·13 — 0·32) = 0·22
Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 27° C. (80° F.) - - - - - - - - -	(0·22 — 0·46) = 0·31	(0·17 — 0·35) = 0·25
Dissolved oxygen taken up in 5 days at 18° C. (65° F.) -	(0·09 — 0·47) = 0·25	(0·10 — 0·44) = 0·23
Chlorine - - - - - - - - - -	(1·88 — 3·00) = 2·42	(2·28 — 6·51) = 4·10

By the time it had reached Ryton Bridge, therefore, the water was again of as good quality, chemically, as above the Rugby outfall. Probably it had re-established its quality a good deal earlier. Some of the polluting matter introduced by the Rugby effluent had of course been deposited as mud, in its course down stream, but apart from the improvement in quality of water brought about by the natural increase in volume of the river, the ammoniacal and organic matters in solution had disappeared through absorption by plants and oxidation. It is interesting to note that, while the organic impurity added by the Rugby effluent had disappeared from the water at Ryton Bridge, the presence of this effluent was still evidenced at the latter point by the relatively high chlorine figure given by the water.

In connection with the question of self-purification of rivers, it is of interest to recall two papers on this subject, written twenty years ago, by O. Löw[†] and by M. von. Pettenkofer.[‡] Löw demonstrates that fresh-water algae can assimilate organic compounds, *i.e.*, soluble decomposition products of putrefying liquids, and that numerous small animal forms appear which feed on algae, and then larger forms which feed on the smaller ones.

Von Pettenkofer, as the result mainly of a study of the river Isar above and below Munich, states that:

"The self-purification of rivers is an undoubted fact."

* * * * *

"It can be decided for any place, and at any time, how the river will appear when all the excreta (from a given place) are sent into it, provided one knows the population of the place and the quantity of water in the river."

* * * * *

"That the oxygen absorbed by all pure river water plays an important part may be proved . . . " (here certain typical polluted rivers are referred to).

* * * * *

"The oxygen acts partly as an oxidizer and partly to enable organisms to live, for there are many which consume oxygen while some of them yield it up again, *i.e.* the green algae and all water vegetation containing chlorophyll."

These few quotations are sufficient to show that von Pettenkofer, so long ago as about the year 1891, appreciated many of the various agencies which participate in the self-purification of rivers, and recognized the interplay of these agencies.

In the appended diagrams, A and B (corresponding to Tables IV. and V., given in Addendum III), the figures for ammoniacal nitrogen, "oxygen absorbed" in 4 hours, and dissolved oxygen absorption in 5 days are given for (*a*) sixty-five samples of river water drawn above effluent outfall; and (*b*) seventy-two samples drawn so far below effluent outfall that no signs of pollution (other than green weeds) were manifest. These samples were mainly drawn between the spring of 1910 and the autumn of 1911, and some of them have already been referred to in Table II.

In both diagrams the curve for dissolved oxygen absorption is arranged so as to show an ascending scale all the way. It will be seen that though the general trend of the curve for ammoniacal nitrogen is upward also, this curve does not agree in detail with that for dissolved oxygen absorption. The concordance, in fact, is not so good as in the earlier samples drawn up to the spring of 1910. In other words, we may sometimes have a sample of river water giving a moderately high figure for dissolved oxygen absorption in 5 days, with a low figure for ammoniacal nitrogen; and, conversely, we may sometimes have a water giving a high figure for ammoniacal nitrogen and a relatively low one for dissolved oxygen absorption.[*] Thus, while generally speaking the two sets run fairly well together, we find at times a river water from which most of the carbonaceous matter has been oxidized, but which is still comparatively rich in ammonia.

Diagram C. gives the curves representing the *average* figures for ammoniacal nitrogen, "oxygen absorbed" in 4 hours and dissolved oxygen absorption in 5 days, yielded by all the samples of river water drawn below effluent outfall, 346 in number (*Cf.* Table II., Part II.-6, p. 135). If this diagram be referred to, it will be seen that while the curve for dissolved oxygen absorption shows a fairly steady rise from "very clean" through "doubtful" to "bad" rivers, the curve for ammoniacal nitrogen is rather higher in the case of the "fairly clean" than the "moderately clean."

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[*] This figure was obtained by deducting the volume of the Coventry effluent from the volume of the river as gauged below the Coventry outfalls.

[†] "Archiv für Hygiene," 1891, p. 261.

[‡] We have been unable to find this in the original, and have only seen an English translation, but it was almost certainly written in the early 'nineties—probably 1891 or 1892.

[*] Taking the samples (16 in number out of 139) giving the figures:
Dissolved oxygen absorption in 5 days - 0·4 or over
Ammoniacal nitrogen - - less than 0·1
14 were drawn in the warm months of the year (May to July), and 2 in a cold month (February).
Taking the samples (13 out of 139) giving the figures:
Ammoniacal nitrogen - - - over 0·1
Dissolved oxygen absorption in 5 days
less than 0·4
11 were drawn in the warmer months (May to October), and 2 in the colder months (January and November).

Taking all our results together, therefore, we consider that, for purposes of a standard test for effluents, the determination of ammoniacal nitrogen, though highly valuable, is less to be relied on as indicating the deoxidizing (*i.e.*, polluting) power of an effluent after its discharge, than the determination of the dissolved oxygen absorption in 5 days.

(2) ALBUMINOID NITROGEN.

The albuminoid nitrogen usually constitutes about one-half to one-third of the total organic nitrogen of a sewage liquor or effluent (*Cf.* the figures of analysis of samples from the various sewage works given in Appendix III. to Fifth Report).

As has been already stated, there is nothing like a definite ratio between the figures for ammoniacal nitrogen and albuminoid nitrogen given by chance samples of either sewages, tank liquors or filter effluents. The albuminoid nitrogen is derived to a considerable extent from the suspended solids present. But even in paper-filtered samples of effluent the ratio of albuminoid to ammoniacal nitrogen varies exceedingly (*Cf.* Accrington Experiments, Fifth Report, Appendix IV., p. 52 *et seq.*).

The determination of "albuminoid ammonia" has been so extensively applied in the analysis of effluents and for their classification that it is necessary to adduce reasons for not recommending the test for purposes of a standard.

Given two domestic (or mainly domestic) sewages of equal strength, or two effluents of approximately the same quality derived from those sewages, the figures for albuminoid nitrogen and for dissolved oxygen absorption would in each case show a good agreement. But when we come to deal with (*a*) a dilute sewage liquor or badly purified effluent, on the one hand, and (*b*) a well purified effluent from a strong sewage, on the other, both giving approximately the same figure for albuminoid nitrogen, we find that their respective powers of taking up dissolved oxygen from water in 2 to 5 days are markedly different. This is well shown in the analyses set forth in the appended Table VI., p. 66A, from which the figures for albuminoid nitrogen and dissolved oxygen absorption may be repeated here (Table VII.) :—

TABLE VII. *Parts per* 100,000.

	Filter effluent.			Diluted sewage.		
	Albuminoid nitrogen.	Dissolved oxygen taken up in—		Albuminoid nitrogen.	Dissolved oxygen taken up in—	
		48 hours.	5 days.		48 hours.	5 days.
No. 1 - - -	0·080	0·17	0·32	0·080	0·60	0·76 + *x*†
No. 2 - - -	0·026	0·13	0·35	0·026	0·17	0·35
No. 3 - - -	0·048	0·12	0·44	0·048	0·67	0·88 + *x*†
No. 4 - - -	0·045	0·06	0·13	0·045	0·78	0·92 + *x*†
No. 5 - - -	0·030	0·11	0·23	0·030	0·56	0·89 + *x*†

Excepting in the case of the second of the above five experiments, where the figures are practically the same for both diluted sewage and effluent, the absorption of oxygen by the diluted sewage is greatly in excess of the absorption by the effluent.

The same thing is shown by the average ratios of albuminoid nitrogen to dissolved oxygen absorption in 5 days, yielded by sewage liquors and effluents. A large number of examples of this are set forth in Table VIII. (p. 68), and the corresponding diagram D (p. 67), from which it is seen that the ratios may be given, approximately‡ :—

For sewage liquors -	about	1 : 30 to 1 : 40
For poorly oxidised effluents	,,	1 : 10 to 1 : 17
For effluents of fair quality	,,	1 : 10
For effluents of good quality,	below	1 : 10

In further illustration of this, some average figures of analysis from two effluents of different quality may be given (Table IX.) :—

TABLE IX.

Place.	Number of samples examined.	Suspended solids.	Albuminoid nitrogen.	Total organic nitrogen.	"Oxygen absorbed" in 4 hours.	Dissolved oxygen taken up in 5 days.
A.	12	6·5	0·26	0·57	2·36	4·38
B.	15	6·3	0·19	0·65	2·61	1·28

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† + *x* denotes that the oxygen present was exhausted.

‡ The samples from any given place necessarily varied in quality, some of the samples of "fair" and "good" effluents being of poor quality, and some of the "poor" effluents being of good quality; but the above averages show clearly enough the general trend of the ratios.

DIAGRAM C.

SHEWING THE AVERAGE FIGURES FOR ALL SAMPLES OF RIVER WATER DRAWN BELOW OUTFALL.

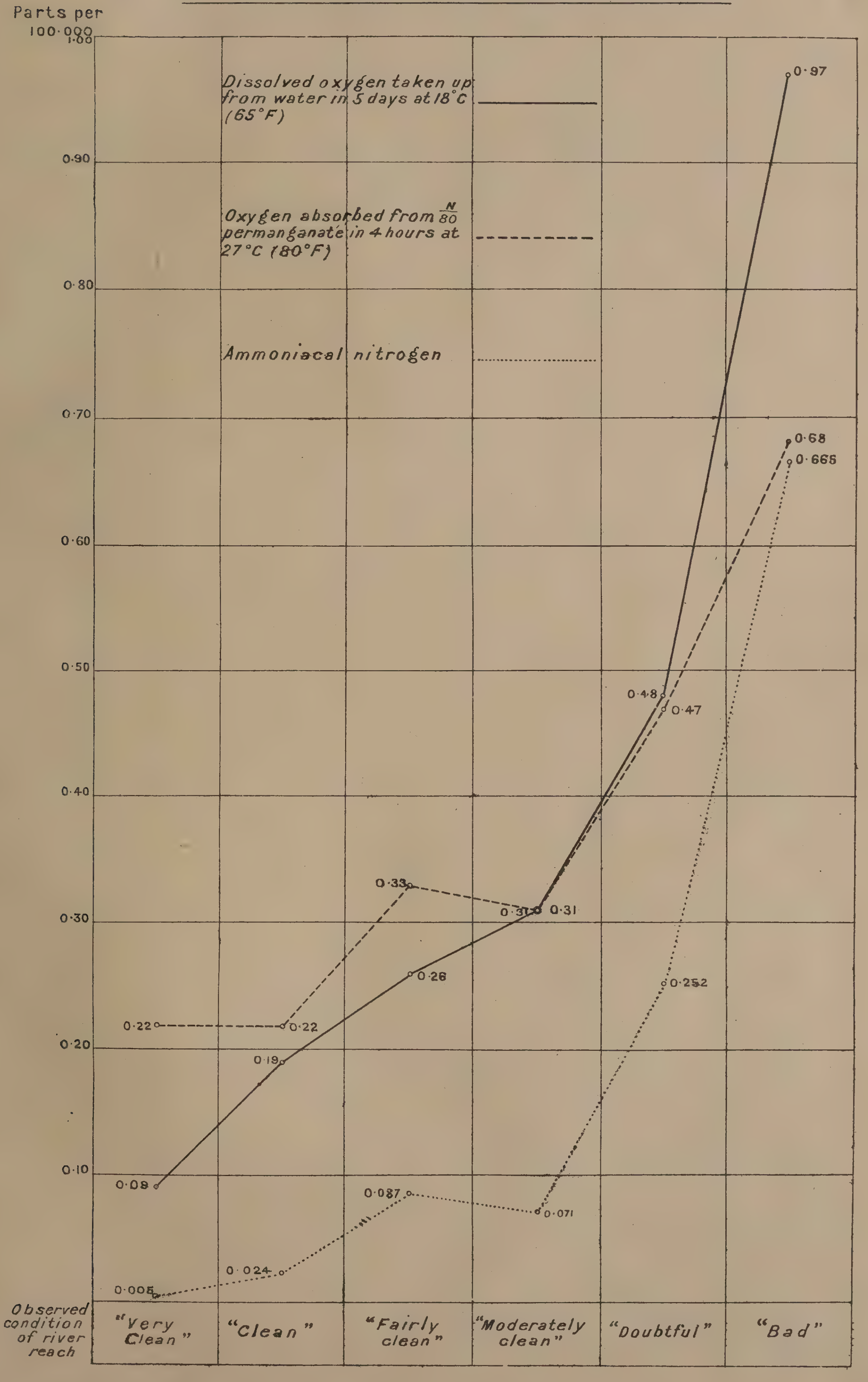

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TABLE VI.

Showing the Absorption of Dissolved Oxygen by Diluted Sewages and Filter Effluents, the Albuminoid Nitrogen being the same in both. *Parts per 100,000 by weight.*

Place.	Samples used.	Date of experiment.	Analysis of effluent.						Analysis of sewage.				Figures given by effluent or diluted effluent.						Figures given by diluted sewage.					
			Ammoniacal nitrogen.	Albuminoid nitrogen.	Nitrous nitrogen.	Nitric nitrogen.	Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.).	Suspended solids.	Ammoniacal nitrogen.	Albuminoid nitrogen.	Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.).	Suspended solids.	Dilution given (vols. of tap-water).	Albuminoid nitrogen in liquid incubated.	Albuminoid nitrogen derived from effluent.	Albuminoid nitrogen derived from tap-water.	Dissolved oxygen taken up after incubation at 18·3° C. (65° F.):—		Dilution given (vols. of tap-water).	Albuminoid nitrogen in liquid incubated.	Albuminoid nitrogen derived from sewage.	Albuminoid nitrogen derived from tap-water.	Dissolved oxygen taken up after incubation at 18·3° C. (65° F.):—	
																	In 48 hours.	In 5 days.					In 48 hours.	In 5 days.
Hendon - - -	Percolation effluent and sewage.	Nov. 7th, 1910.	0·92	0·08	Not estimated.		0·63	—	7·37	0·97	8·31	All the samples of sewage were settled overnight, and then the liquid portion siphoned off for use.	No dilution.	0·080	0·080	—	0·17	0·32	12·3	0·080	0·07	0·01	0·60	0·76+x*
Hendon - - -	Contact effluent and sewage.	Nov. 8th, 1910.	2·72	0·20	Not estimated.		2·38	—	7·25	0·90	8·11		9 vols.	0·026	0·020	0·006	0·13	0·35	46·6	0·026	0·019	0·007	0·17	0·35
Ealing - - -	Percolation effluent and sewage.	Nov. 21st, 1910.	0·89	0·21	0·20	3·23	2·10	Considerable.	4·25	1·30	14·07		4 vols.	0·048	0·042	0·006	0·12	0·44	30·2	0·048	0·041	0·007	0·67	0·88+x
Kenilworth - -	Percolation effluent and sewage.	Nov. 23rd, 1910.	0·03	0·045	0·00	7·68	0·92	Moderate.	10·51	1·59	19·23		No dilution.	0·045	0·045	—	0·06	0·13	40·6	0·045	0·038	0·007	0·78	0·92+x
Stratford-on-Avon -	Percolation effluent and sewage.	Nov. 24th, 1910.	0·10	0·076	0·00	3·20	1·10	Moderate.	2·10	0·75	12·36		2 vols.	0·030	0·025	0·005	0·11	0·23	30·3	0·030	0·023	0·007	0·56	0·89+x

* +x denotes that the oxygen was exhausted.

The first effluent of Table IX. was a poorly oxidised one from a weak sewage; the second a well oxidized one from a strong sewage. In the former case the ratio of albuminoid nitrogen to dissolved oxygen absorption in 5 days is 1 : 17, while in the latter it is 1 : 7.

It follows, therefore, from the foregoing considerations, that the albuminoid nitrogen is a less valuable index than the 5 days' dissolved oxygen absorption of the degree of fermentation which a sewage liquor has undergone; or, to put it differently, it gives a less correct measure of the more readily fermentable matter remaining in an effluent.

(3) ORGANIC NITROGEN.

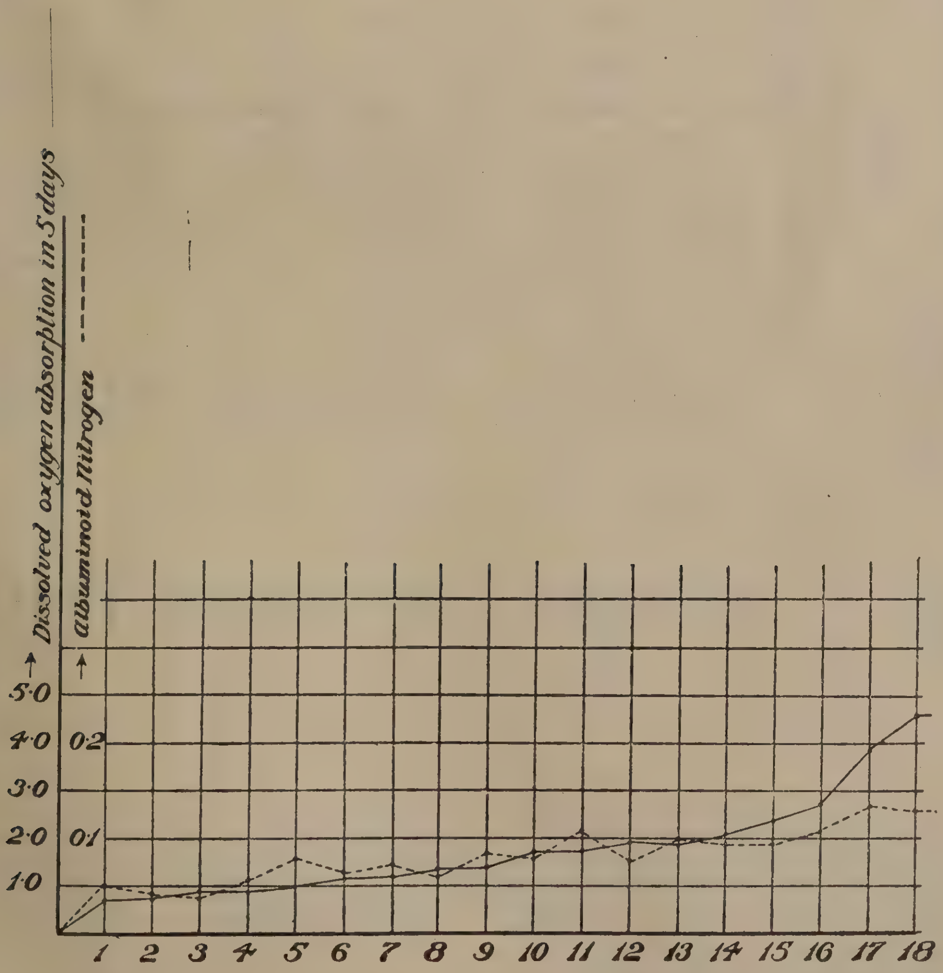
The arguments against the adoption of the albuminoid nitrogen figure in effluents for purposes of a standard apply also to the figure for total organic nitrogen. As is well known, the organic nitrogen of an effluent is, as a rule, twice to three times as great as the albuminoid nitrogen. This has been abundantly evident throughout the work done for the Commission, and reference need merely be made now to the large number of figures bearing upon the point in Appendices III. and IV. of the Fifth Report.

It should, however, be repeated here that our method of determining total organic nitrogen has been an indirect one, *i.e.*, the figure has been arrived at by subtracting from the total nitrogen, as determined by the Kjeldahl method, the sum of the ammoniacal, nitrous and nitric nitrogens. An indirect method is seldom as good as a direct one, and no doubt had the organic nitrogen been also estimated by the direct method of Frankland, there would have been differences in the case of individual figures by the two methods; but we do not think that *average* figures obtained (*a*) indirectly and (*b*) directly, would have differed much.

In Table VIII., p. 68, the average ratios of albuminoid nitrogen to 5 days' dissolved oxygen absorption have been given for a large number of different samples of sewage liquors and effluents. The corresponding average ratios of organic nitrogen to 5 days' dissolved oxygen absorption are now given in Table X., p. 69.

Diagram D., corresponding to Table VIII., Group II., Page 68.

Parts per 100,000. Shewing ratio of Albuminoid Nitrogen to Dissolved Oxygen absorption in 5 days.



The order in Diagram D is as follows: No. 1, Stratford-on-Avon; No. 2, Halstead; No. 3, Buxton; No. 4, Consett; No. 5, Coventry; No. 6, Cambridge; No. 7, Wilpshire; No. 8, Alderley Edge; No. 9, Kenilworth; No. 10, Hartley Wintney; No. 11, Chelmsford; No. 12, Berkhamsted; No. 13, Lincoln; No. 14, Rugby; No. 15, Nuneaton; No. 16, Swindon; No. 17, Middleton; No. 18, Tiverton.

TABLE VIII.

Showing Ratio of Albuminoid Nitrogen to Dissolved Oxygen Absorption in 5 Days, etc.

(Table arranged in order of Dissolved Oxygen Absorption.)

—	Albuminoid nitrogen.	Dissolved oxygen absorption in 5 days.	Ratio of albuminoid nitrogen (= 1) to dissolved oxygen absorption in 5 days.		Number of samples examined.	Calculated strength* (including volatile solids and not giving credit for nitrate).	Ratio of dissolved oxygen absorption in 5 days (= 1) to calculated strength.
			Extremes.	Average.			
Group I.—Sewages and Tank Liquors.							
Malton	1·22	47·3	1 : 21 to 1 : 82	1 : 40	14	151	1 : 3·2
Huntingdon	1·25	43·1	1 : 24 to 1 : 60	1 : 33	7	126	1 : 2·9
St. Neots	1·00	32·9	1 : 17 to 1 : 46	1 : 30	12	125	1 : 3·9
Barnoldswick	0·49	14·6	1 : 15 to 1 : 42	1 : 29	11	48	1 : 3·3
Wye	0·96	19·0	1 : 14 to 1 : 45 + x	1 : 27	8	94	1 : 4·9
Pickering	0·65	24·5	1 : 20 to 1 : 72	1 : 40	11	68	1 : 2·8
Ollerton	0·25	9·9	1 : 38 and 1 : 42	1 : 40	2	32	1 : 3·2
Group II.—Effluents.							
Tiverton	0·26	4·57	1 : 6 to 1 : 31	1 : 17	11	16·3	1 : 3·6
Middleton	0·27	3·94	1 : 6 to 1 : 29	1 : 14	11	21·5	1 : 5·5
Swindon	0·22	2·72	1 : 4 to 1 : 18	1 : 10	11	15·0	1 : 5·5
Nuneaton	0·19	2·46	1 : 2 to 1 : 32	1 : 12	17	12·0	1 : 4·9
Rugby	0·19	2·03	1 : 3 to 1 : 41	1 : 12	16	12·1	1 : 6·0
Lincoln	0·20	1·95	1 : 3 to 1 : 22	1 : 10	18	12·7	1 : 6·5
Berkhamsted	0·15	1·94	1 : 1 to 1 : 25	1 : 11	13	9·2	1 : 4·6
Chelmsford	0·21	1·74	1 : 3 to 1 : 22	1 : 11	18	13·5	1 : 7·8
Hartley Wintney	0·15	1·68	1 : 4 to 1 : 22	1 : 11	13	10·3	1 : 6·1
Kenilworth	0·17	1·33	1 : 1 to 1 : 15	1 : 5	14	9·9	1 : 7·4
Alderley Edge	0·12	1·28	1 : 3 to 1 : 21	1 : 9	15	8·1	1 : 6·3
Wilpshire	0·14	1·16	1 : 3 to 1 : 16	1 : 9	11	7·2	1 : 6·2
Cambridge	0·13	1·15	1 : 3 to 1 : 17	1 : 9	12	10·2	1 : 8·9
Coventry	0·16	1·00	1 : 4 to 1 : 10	1 : 7	19	12·9	1 : 12·9
Consett	0·11	0·90	1 : 5 to 1 : 10	1 : 9	8	5·8	1 : 6·4
Buxton	0·08	0·86	1 : 3 to 1 : 25	1 : 10	20	5·9	1 : 6·9
Halstead	0·09†	0·79	1 : 4 to 1 : 18	1 : 10	7	6·3	1 : 8·0
Stratford-on-Avon	0·10	0·63	1 : 2 to 1 : 10	1 : 6	9	4·7	1 : 7·5

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* *Cf.* Appendix IV. to Fifth Report, pp. 4 and 12. In calculating the "strengths," a good many interpolations for the organic nitrogen figure and a few for the figure for volatile solids have been made.

TABLE X.

Showing Ratio of Organic Nitrogen to Dissolved Oxygen Absorption in 5 Days.

(Table arranged in order of Dissolved Oxygen Absorption.)

	Organic nitrogen.	Dissolved oxygen absorption in 5 days.	*Average* ratio of organic nitrogen to dissolved oxygen absorption in 5 days.	Number of samples examined.
	Group I.—Sewages and Tank Liquors.			
Malton - - - - - -	3·09	48·5	1 : 15·7	13
Huntingdon - - - - -	2·77	43·1	1 : 15·5	6
St. Neots - - - - - -	2·92	35·7	1 : 12·2	10
Pickering - - - - - -	1·30	24·1	1 : 18·5	10
Wye - - - - - - -	2·06	19·0	1 : 9·2	7
Barnoldswick - - - - -	0·94	14·6	1 : 15·5	11
Ollerton - - - - - -	0·80	9·9	1 12·4	2
	Group II.—Effluents.			
Tiverton - - - - - -	0·57	4·72	1 : 8·3	10
Middleton - - - - - -	0·59	3·94	1 : 6·7	11
Swindon - - - - - -	0·55	3·64	1 : 6·6	9
Nuneaton - - - - - -	0·51	2·56	1 : 5·0	14
Lincoln - - - - - -	0·64	2·26	1 : 3·5	13
Rugby - - - - - -	0·45	2·16	1 : 4·8	12
Hartley Wintney - - - -	0·34	1·82	1 : 5·3	11
Chelmsford - - - - -	0·44	1·72	1 : 3·9	16
Berkhamsted - - - - -	0·44	1·69	1 : 3·8	11
Kenilworth * - - - - -	0·65	1·43	1 : 2·2	12
Alderley Edge - - - - -	0·33	1·30	1 : 3·9	13
Wilpshire - - - - - -	0·32	1·21	1 : 3·7	10
Cambridge - - - - - -	0·39	1·21	1 : 3·2	11
Coventry - - - - - -	0·44	1·06	1 : 2·4	14
Stratford-on-Avon - - - -	0·48	1·06	1 : 2·2	7
Buxton - - - - - -	0·29	0·94	1 : 3·2	11
Consett - - - - - -	0·18	0·93	1 : 5·2	4
Halstead - - - - - -	0·28	0·89	1 : 3·2	5

It will be observed that Table X. comprises rather fewer samples than Table VIII. The order of the different places is, however, substantially the same in both. Table X. shows that the average ratio of organic nitrogen to dissolved oxygen absorption in 5 days is :—

For sewages and sewage liquors	about	1 : 12 to 1 : 18	
For poorly oxidised effluents	,,	1 : 6 to 1 : 8	
For fair effluents - -	,,	1 : 3 to 1 : 5	
For good effluents - -	,,	1 : 2 to 1 : 3	

Comparing Tables VIII. and X., it is seen that the average ratio of organic nitrogen to dissolved oxygen absorption in 5 days is throughout from two to three times the average ratio of albuminoid nitrogen to dissolved oxygen absorption.

If Table IX. page 66, be again referred to—this time for the figures for organic nitrogen and dissolved oxygen absorption—it will be observed that both sets of samples quoted there contained, on the average, about equal amounts of organic nitrogen, but that the one took up in 5 days something like three-and-a-half times as much oxygen as the other.

As in the case of the albuminoid nitrogen figure, therefore, the figure for total organic nitrogen cannot be relied upon to give a correct measure of the more readily fermentable organic matter remaining in an effluent, and for this reason we consider that it is not to be recommended for purposes of a standard.

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* The case of Kenilworth deserves mention. This effluent is highly oxidised, but it contains a considerable quantity of suspended solids, which are largely responsible for the figure for dissolved oxygen absorption.

(4) OXYGEN ABSORBED FROM PERMANGANATE IN 4 HOURS.

The oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.) represents something like one-tenth of the total oxidizability of an ordinary sewage or tank liquor. The ratio is, as a rule, somewhat greater in the case of a moderately well purified effluent (say, one-sixth or one-seventh) and greater still (say, one-third to one-fifth) in the case of a well oxidized effluent. But it is difficult to give anything more than rough approximations here, since permanganate has no action on the ammonia of a sewage liquor or effluent, and this constitutes part of the oxidizable matter.*

The figures for albuminoid nitrogen and for oxygen absorbed in 4 hours, which are obtained in the analysis of domestic or mainly domestic sewage liquors and their effluents, bear a fairly even average ratio to one another, provided that a sufficient number of samples from any one place are grouped together; but the ratio between individual samples may vary very much, as is seen from the figures of analysis quoted in Table XI.

In both tests a partial oxidation of the organic matter present is brought about by the oxygen of dilute permanganate of potash—in the one case in alkaline solution at boiling temperature, and in the other in acid solution, usually at a temperature of 27° C. (80° F.).

Because of the fair concordance in results given by the two tests, the argument adduced against adopting the figure for albuminoid nitrogen (as compared with that for the 5 days' dissolved oxygen absorption), for purposes of a standard, applies also, though in lesser degree, to the oxygen absorbed from permanganate.

TABLE XI.

SHOWING RATIO OF ALBUMINOID NITROGEN TO "OXYGEN ABSORBED" FROM $\frac{N}{8}$ PERMANGANATE IN 4 HOURS AT 27° C. (80° F.).

(Table arranged in same order as Table VIII.)

	Albuminoid nitrogen.	"Oxygen absorbed" in 4 hours at 27° C. (80° F.).	Ratio of albuminoid nitrogen (= 1) to "oxygen absorbed."		Number of samples examined.
			Extremes.	Average.	
		Group I.—Sewages and Sewage Liquors.			
Malton - - - -	1·22	18·53	1 : 8·7 — 1 : 31·0	1 : 15·3	14
Huntingdon - - -	1·25	18·25	1 : 9·1 — 1 : 22·0	1 : 14·1	7
St. Neots - - - -	1·00	13·51	1 : 9·5 — 1 : 18·0	1 : 13·4	12
Pickering - - - -	0·65	7·54	1 : 8·6 — 1 : 16·0	1 : 12·1	11
Wye - - - - -	0·96	10·45	1 : 5·6 — 1 : 17·0	1 : 11·2	8
Barnoldswick - - -	0·49	4·62	1 : 6·7 — 1 : 14·0	1 : 9·2	11
Ollerton - - - -	0·25	4·16	1 : 13·0 and 1 : 19·0	1 : 16·0	2
		Group II.—Effluents.			
Tiverton - - - -	0·26	2·45	1 : 6·6 — 1 : 13·0	1 : 9·6	11
Middleton - - - -	0·27	2·61	1 : 4·6 — 1 : 13·0	1 : 9·2	11
Swindon - - - -	0·22	1·82	1 : 6·2 — 1 : 11·0	1 : 8·5	11
Nuneaton - - - -	0·19	2·20	1 : 8·3 — 1 : 16·0	1 : 11·3	17
Rugby - - - -	0·19	1·76	1 : 5·0 — 1 : 16·0	1 : 9·9	16
Lincoln - - - -	0·20	1·78	1 : 4·4 — 1 : 13·0	1 : 9·3	18
Berkhamsted - - -	0·15	1·04	1 : 3·6 — 1 : 11·0	1 : 6·8	13
Chelmsford - - - -	0·21	1·80	1 : 5·8 — 1 : 14·0	1 : 9·2	18
Hartley Wintney - -	0·15 13 samples	1·78	1 : 3·8 — 1 : 16·0	1 : 10·7	12
Kenilworth - - - -	0·17	2·41	1 : 13·0 — 1 : 19·0	1 : 15·1	14
Alderley Edge - - -	0·12	1·19	1 : 4·3 — 1 : 19·0	1 : 11·1	15
Wilpshire - - - -	0·14	0·93	1 : 3·5 — 1 : 12·0	1 : 7·6	11
Cambridge - - - -	0·13	1·06	1 : 4·2 — 1 : 12·0	1 : 9·5	12
Coventry - - - -	0·16	1·15	1 : 3·9 — 1 : 10·0	1 : 7·1	19
Consett - - - -	0·11	0·79	1 : 3·6 — 1 : 13·0	1 : 7·8	8
Buxton - - - -	0·08	0·82	1 : 5·0 — 1 : 22·0	1 : 10·8	19
Halstead - - - -	0·08	0·73	1 : 5·0 — 1 : 13·0	1 : 9·5	7
Stratford-on-Avon - -	0·10	1·17	1 : 6·9 — 1 : 16·0	1 : 11·7	9

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* *Cf.* Fifth Report, Appendix IV., p. 1, *et seq.* and p. 10, *et seq.*

In Table XII., the average ratios, together with the extreme ratios, of "oxygen absorbed" to dissolved oxygen absorption are given for the same sets of samples as have already been referred to in Tables VIII. and XI. The average ratios of Table XII. could of course be calculated from the ratios in the two former Tables, but it is better to give the ratios as deduced from the analytical figures found.

Table XII. shows that the average ratio of the two tests ("oxygen absorbed" : dissolved oxygen absorption) is much less in the case of sewage liquors than of effluents. With increasing purification of effluent, the component ratio figures approximate to one another; with a highly purified effluent, the original ratio is inverted.

TABLE XII.

SHOWING RATIO OF "OXYGEN ABSORBED" FROM $\frac{N}{8}$ PERMANGANATE IN 4 HOURS AT 27° C. (80° F.) TO DISSOLVED OXYGEN ABSORPTION IN 5 DAYS AT 18° C. (65° F.).

(Table Arranged in the Order of Dissolved Oxygen Absorption.)

	"Oxygen absorbed" in 4 hours at 27° C.	Dissolved oxygen absorption in 5 Days at 18° C.	Ratio of "oxygen absorbed" to dissolved oxygen absorption.		Number of samples examined.
			Extremes.	Average.	
	Group I.—Sewages and Sewage Liquors.				
Malton	18·53	47·3	1 : 1·65 — 1 : 3·60	1 : 2·5	14
Huntingdon	18·25	43·1	1 : 1·07 — 1 : 3·03	1 : 2·4	7
St. Neots	13·51	32·9	1 : 1·15 — 1 : 3·32	1 : 2·4	12
Pickering	7·54	24·5	1 : 1·91 — 1 : 4·84	1 : 3·5	11
Wye	10·45	19·0	1 : 1·40 — 1 : 2·80	1 : 2·3	8
Barnoldswick	4·62	14·6	1 : 2·07 — 1 : 4·65	1 : 3·2	11
Ollerton	4·16	9·9	1 : 2·16 and 1 : 3·03	1 : 2·6	2
	Group II.—Effluents.				
Tiverton	2·45	4·57	1 : 0·86 — 1 : 2·43	1 : 1·7	11
Middleton	2·61	3·94	1 : 0·65 — 1 : 2·34	1 : 1·4	11
Swindon	1·82	2·72	1 : 0·52 — 1 : 2·89	1 : 1·2	11
Nuneaton	2·20	2·46	1 : 0·27 — 1 : 2·27	1 : 1·1	17
Rugby	1·76	2·03	1 : 0·58 — 1 : 2·82	1 : 1·2	16
Lincoln	1·78	1·95	1 : 0·35 — 1 : 1·92	1 : 1·0	18
Berkhamsted	1·04	1·94	1 : 0·1(?)— 1 : 4·71	1 : 1·8	13
Chelmsford	1·80	1·74	1 : 0·55 — 1 : 1·86	1 : 1·2	18
Hartley Wintney	1·78	1·68	1 : 0·10 — 1 : 3·78	1 : 1·2	12
Kenilworth	2·41	1·33	1 : 0·06 — 1 : 1·05	1 : 0·4	14
Alderley Edge	1·19	1·28	1 : 0·20 — 1 : 1·91	1 : 1·0	15
Wilpshire	0·93	1·16	1 : 0·63 — 1 : 1·94	1 : 1·2	11
Cambridge	1·06	1·15	1 : 0·41 — 1 : 1·66	1 : 1·0	12
Coventry	1·15	1·00	1 : 0·47 — 1 : 1·30	1 : 0·9	19
Consett	0·79	0·90	1 : 0·82 — 1 : 2·68	1 : 1·3	8*
Buxton	0·82	0·86	1 : 0·25 — 1 : 2·85	1 : 1·1	19
Halstead	0·73	0·79	1 : 0·45 — 1 : 3·12	1 : 1·4	7
Stratford-on-Avon	1·17†	0·63	1 : 0·16 — 1 : 1·13	1 : 0·6	9‡

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* Omitting an altogether abnormal sample.

† Taking, for one estimation, the figure 0·88 as representing $\frac{N}{8}$ permanganate, from an actual figure of 0·55, obtained with $\frac{N}{80}$ permanganate.

‡ Omitting two abnormal samples.

If Tables VIII. and XII. be compared, it will be seen from Table XIII. that the *average* ratios in the two cases are very concordant, allowing for the fact that in Table VIII. the ratio is about ten times smaller than in Table XII., thus:—

TABLE XIII.

	Table VIII. Average ratio of albuminoid nitrogen to dissolved oxygen absorption.	Table XII. Average ratio of "oxygen absorbed" to dissolved oxygen absorption.
Sewages and Sewage Liquors.		
Malton	1 : 40	1 : 2·5
Huntingdon	1 : 33	1 : 2·4
St. Neots	1 : 30	1 : 2·4
Pickering	1 : 40	1 : 3·5
Wye	1 : 27	1 : 2·3
Barnoldswick	1 : 29	1 : 3·2
Ollerton	1 : 40	1 : 2·6
Effluents.		
Tiverton	1 : 17	1 : 1·7
Middleton	1 : 14	1 : 1·4
Swindon	1 : 10	1 : 1·2
Nuneaton	1 : 12	1 : 1·1
Rugby	1 : 12	1 : 1·2
Lincoln	1 : 10	1 : 1·0
Berkhamsted	1 : 11	1 : 1·8
Chelmsford	1 : 11	1 : 1·2
Hartley Wintney	1 : 11	1 : 1·2
Kenilworth	1 : 5	1 : 0·4
Alderley Edge	1 : 9	1 : 1·0
Wilpshire	1 : 9	1 : 1·2
Cambridge	1 : 9	1 : 1·0
Coventry	1 : 7	1 : 0·9
Consett	1 : 9	1 : 1·3
Buxton	1 : 10	1 : 1·1
Halstead	1 : 10	1 : 1·4
Stratford-on-Avon	1 : 6	1 : 0·6

Table XIV., p. 73, gives an analogous set of average ratio figures to those in Table XII., collated from a large number of analyses of sewage liquors and effluents carried out for the Commission by various sewage authorities in 1910–11. Looking at this Table it is seen that the same conclusions hold good as in the case of Table XII., viz., (1) that the individual ratios of the two tests (4 hours : 5 days) show marked variations; (2) that the average ratios are much less divergent; (3) that the average ratio is lowest in the case of a sewage or tank liquor and highest in the case of a well purified effluent.

In each case the tests were carried out by the various authorities on the whole sample, the sample after settlement for 2 hours, and the paper-filtered sample. The results from the last two are not shown in Table XIV., but, speaking generally, the suspended solids present had little effect on the ratio of "oxygen absorbed" to dissolved oxygen absorption in 5 days, either in the sewage liquors or the effluents; in other words, the ratio did not differ materially in the original sample, the two hours settled sample and the paper-filtered sample.

For sewage liquors and filter effluents, therefore, the average ratios of oxygen absorbed in 4 hours from $\frac{N}{8}$ permanganate (= 1) to dissolved oxygen taken up in 5 days are, approximately:—

For sewages and tank liquors	about	1 : 2·5 to 1 : 3·5
For poorly oxidised effluents	,,	1 : 1·5
For fairly well oxidised effluents	,,	1 : 1
For well oxidised effluents	,,	1 : 1 to 1 : 0·5

Streams Samples: First Series.

Leaving the consideration of sewage liquors and effluents, as regards the two tests under discussion, and reverting to the river waters of Table I., p. 64A, we find that in twenty-nine pairs of comparative samples of polluted water, already mentioned on page 64, there was concordance between the "oxygen absorbed" and the dissolved oxygen absorption tests in twenty cases, *i.e.*, sixteen showed a decrease and four an increase in the lower sample in both tests. Further, the percentage decrease or increase was greater in the dissolved oxygen absorption in seventeen cases, as against three cases in which it was greater in the "oxygen absorbed."

An examination of the figures given by the above fifty-eight samples of more or less polluted waters also shows, broadly:—

(1) That the more organic suspended solids there are in a sample of polluted water, the higher is the figure for dissolved oxygen taken up as compared with that for "oxygen absorbed" from permanganate.

(2) That the purer the sample of water, the lower is the figure for dissolved oxygen taken up, as compared with that for "oxygen absorbed."

(3) That as a water becomes less pure, the figure for dissolved oxygen absorption tends to increase more rapidly than the figure for "oxygen absorbed."

Streams Samples: Second Series.

Later results obtained from nineteen further pairs of samples of river water, drawn between the spring of 1910 and the autumn of 1911 (Table II., p. 64B), bear out the earlier results which have just been cited. In the larger number of these later samples the dissolved oxygen absorption test showed itself more delicate than the "oxygen absorbed" from permanganate.

Diagram C, facing p. 66, shows the curves representing the average figures for ammoniacal nitrogen, "oxygen absorbed" and dissolved oxygen absorption for all the samples of river water drawn below effluent outfall, plotted against the observed condition of the stream. The average figures themselves are to be found in Table II. of Part II., Section 6.

From this diagram it will be seen that, with the purer samples of water, up to an observed stream condition of "fairly clean," the "oxygen absorbed" curve is higher than that for dissolved oxygen absorption. The two curves run well together until a point is reached, corresponding to a figure of about 0·45 for each test, where the observed condition of the stream becomes "doubtful." After that, the curve for dissolved oxygen absorption rises more quickly than that for "oxygen absorbed." In other words, the dissolved oxygen absorption figures show the greater range, starting from a lower point with the clean waters and ending at a higher one with the bad waters.

Lastly, to quote from the Channel Experiments (Part III. of this Appendix), the average figure for "oxygen absorbed" in 4 hours, in the Caterham effluent as it entered the channel, was 2·93 (18 samples; omitting the three last samples of effluent, after it had fallen off in quality), while the corresponding average figure in the Chorley tank liquor

TABLE XIV.

Showing Ratio of Oxygen absorbed from $\frac{N}{8}$ Permanganate in 4 hours at 27° C. (80° F.) to Dissolved Oxygen Absorption in 5 Days at 18·3° C. (65° F.). The Figures in this Table were obtained by the respective Sewage Authorities.

Place.	Nature of sample.	Chance or average samples	Average figures for "oxygen absorbed" in 4 hours.	Average figures for dissolved oxygen absorption in 5 days.	Extreme ratios. "4 hours" : "5 days."	Average ratio — "4 hours" : "5 days."	Number of samples examined.
Birmingham	Septic tank liquor	Average	10·56	22·26	1 : 1·25 - 1 : 3·23	1 : 2·1	7
Oldham	Settled sewage	Average	7·30	20·75	1 : 1·55 — 1 : 3·84	1 : 2·8	5
Leeds	Precipitation liquor	Chance	15·59	20·2	1 : 0·79 — 1 : 1·85	1 : 1·3	36
Norwich	Septic tank liquor	Chance	7·27	18·34	1 : 0·85 — 1 : 4·73	1 : 2·4	8
Oldham	Single contact effluent	Chance	3·85	10·47	1 : 2·04 — 1 : 3·16	1 : 2·7	8
Sheffield	” ” ”	Chance	3·76	4·64	1 : 0·42 — 1 : 1·77	1 : 1·2	28
Manchester	Double contact effluent	Chance	1·94	2·49	1 : 0·60 — 1 : 3·50	1 : 1·3	13
Bury	” ” ”	Average	2·66	2·48	1 : 0·49 — 1 : 1·45	1 : 0·9	32
Halifax	” ” ”	Chance	1·62	1·99	1 : 0·32 — 1 : 1·84	1 : 1·2	7
Burnley	” ” ”	Chance	1·20	1·49	1 : 0·41 — 1 : 2·46	1 : 1·3	28
Chester	Percolation effluent	9 average 25 chance	2·32	3·91	1 : 1·07 — 1 : 2·73	1 : 1·7	34
Salford	” ”	Chance	3·16	3·74	1 : 0·46 — 1 : 4·66	1 : 1·1	14
Leeds	” ”	Chance	4·05	3·53	1 : 0·51 — 1 : 2·17	1 : 0·8	24
Birmingham	” ”	Chance	2·49	2·70	1 : 0·52 — 1 : 1·89	1 : 1·1	9
Huddersfield	” ”	Chance	2·56	1·76	1 : 0·36 — 1 : 0·94	1 : 0·7	50
Accrington	” ”	Chance	2·16	1·74	1 : 0·39 — 1 : 1·38	1 : 0·8	32
Blackburn	” ”	Chance	2·05	1·45	1 : 0·37 — 1 : 1·19	1 : 0·7	34
Bradford	” ”	Chance	1·14	1·01	1 : 0·36 — 1 : 2·51	1 : 0·9	28
Stratford-on-Avon	” ”	Chance	0·95	0·45	1 : 0·24 — 1 : 0·66	1 : 0·5	5
Croydon	Land effluent	Chance	1·39	0·76	1 : 0·23 — 1 : 1·15	1 : 0·5	24
Coventry	” ”	Chance	0·75	0·33	1 : 0·13 — 1 : 0·83	1 : 0·4	13

as entering channel was 2·65 (19). The corresponding figures for dissolved oxygen absorption in 5 days were :—

Caterham effluent = 1·02 (16),
Chorley tank liquor = 4·91 (16).

In these two cases, the channels were dealing with (1) a fairly well oxidized effluent from a strong sewage; and (2) a weak precipitation liquor. The channel at Caterham (until the effluent had deteriorated towards the end of the experiment) showed only green growths, while the channel at Chorley had much grey growth and black putrid mud.

The permanganate test, because of its simplicity and the ease and rapidity with which it can be carried out, is of immense value in the laboratory and in the conduct of a sewage works or farm. But we think it is clear, from the various considerations which have been brought forward in this section of the memorandum, that for purposes of a standard test it gives a less correct measure of the more readily fermentible matter remaining in an effluent than does the 5 days' dissolved oxygen absorption test.

(5) THE INCUBATOR TEST (AS JUDGED BY SMELL).

This test, originally introduced by Mr. Scudder[1], is of much practical value in daily work, but for purposes of a standard it is necessarily less stringent than the dissolved oxygen absorption test. The incubator test has been studied, with the object of making it more or less quantitative, by Spitta*, Spitta and Weldert†, and by Phelps‡.

The absorption of dissolved oxygen constitutes the first stage of the incubator test. When an effluent containing both oxygen and nitrate in solution is incubated in a full bottle at, say, 27° C. (80° F.), the dissolved oxygen is used up (practically speaking) by the oxidizable matter of the effluent before the nitrite and nitrate are called upon to supply oxygen; or, perhaps more correctly, when the oxygen has just been used up, the nitrate remains in (virtually) its original amount. Then, after nitrite and nitrate have given up their oxygen, the sulphate present is attacked, and the loss of its oxygen results in the formation of sulphuretted hydrogen, *i.e.*, there is offensive putrefaction.

As an instance of the using up of dissolved oxygen before nitrate, the following case may be cited (*Cf.* also Part II. Section 9, p. 164 *et seq.*)

A Hendon percolation effluent of fair quality, drawn on May 30th, 1911, was diluted with an equal volume of tap water and the mixture was analysed on June 1st; a second analysis was made on another portion of the mixture after incubation in a full bottle at 18° to 23° C. for 26 days. The following figures were obtained :—

Parts per 100,000.

	June 1st.	June 27th.
Ammoniacal nitrogen - -	1·02	0·71
Albuminoid nitrogen - -	0·10	0·12
Total organic nitrogen -	0·20	—
Nitrous nitrogen - - -	0·0	0·10
Nitric nitrogen - - -	0·73	0·55
Total nitrogen (by Kjeldahl)	1·95	—
"Oxygen absorbed" from $\frac{N}{8}$ permanganate in 4 hours at 27° C. - - -	0·68	0·55

Ten bottles, of about 350 c.c. capacity each, were filled with the mixture of effluent and water on June 1st, and placed in the 18° C. incubator, and the dissolved oxygen, nitrite and nitrate of these were estimated on the dates given in Table XV. The weather was very warm during the first part of the experiment and the temperature of the incubator rose as high as 23° C., no ice having been used.

TABLE XV.

Parts per 100,000.

Number of bottle.	Date of analysis.	Temperature of incubator.	Oxygen in solution.	Nitric nitrogen.	Nitrous nitrogen.	Nitric plus nitrous nitrogen.
1	June 1st	—	0·80	0·73	0·00	0·73
2	,, 2nd	20° C.	0·64	0·73	0·00	0·73
3	,, 3rd	20°	0·67	0·60	0·00	0·60
4	,, 6th	23°	0·25	0·47	0·08	0·55
5	,, 7th	21°	0·20	0·62	0·06	0·68
6	,, 9th	20·3°	0·0	0·70	0·10	0·80
7	,, 12th	about 17° §	0·0	0·50	0·10	0·60
8	,, 15th	20°	0·0	0·57 ‖	0·08	0·65
9	,, 19th	19·5°	0·0	0·55	0·12	0·67
10	,, 27th	18·5°	0·0	0·55	0·10	0·65

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[1] Mr. Scudder determines the "oxygen absorbed" in three minutes from permanganate, before and after incubation.

* "Archiv fur Hygiene," 1903, Vol. XLVI., p. 113.

† "Mittheilung aus der Königlichen Prüfungsanstalt fur Wasserversorgung und Abwässerbeseitigung zu Berlin," 1906, p. 161.

‡ Contributions from the Sanitary Research Laboratory of the Mass. Inst. Tech., 1909, Vol. V., p. 74.

§ From memory.

‖ There may have been a slight loss here, but it is improbable.

The foregoing table shows that while the oxygen in solution was being gradually reduced in 6 days from 0·80 to 0, the oxidized (nitrous and nitric) nitrogen remained substantially constant. The latter showed but little diminution at the end of the 26 days that the experiment lasted, the dissolved oxygen originally present having almost sufficed for the oxidation of all carbonaceous matter.

If the incubator test were to be applied for purposes of a standard, it would not necessarily always represent the same thing that the dissolved oxygen absorption test does. Thus, a partially oxidized effluent containing a considerable quantity of nitrate might withstand incubation longer than one whose organic matter was really better oxidized, but which happened to be poor in nitrate. The latter effluent would have a less de-oxygenating action upon the water of a stream.

Since an effluent at ordinary temperature contains only about 1 part by weight of oxygen in solution per 100,000 (about 7 cc. per litre), assuming it to be thoroughly aerated, it would, in the absence of any nitrate, (usually) putrefy on incubation after using up that 1 part of oxygen. If it contained, in addition, 1 part of nitric nitrogen, this would be equivalent to a further 3 parts of oxygen (*Cf.* Fifth Report, Appendix IV., p. 12).

As illustrating the difference in practice between the results of the incubator test and the 5 days' dissolved oxygen absorption test (putting the standard for the latter at 2·0 parts oxygen per 100,000 of effluent, provisionally), we give, in Table XVI., the comparative records from a large number of effluent samples of different quality.*

TABLE XVI.

Comparison of the Incubator and the 5 Days' Dissolved Oxygen Absorption Tests.

Place.	Incubator test, as judged by smell. Number of samples which failed.	5 days' dissolved oxygen absorption test (limit = 2·0 parts oxygen). Number of samples which failed.	Number of samples failing on incubation which passed the 5 days' test.	Number of samples failing in the 5 days' test which passed the incubator test.
Tiverton - - - - -	9 out of 12	9 out of 12	0	0
Middleton - - - - -	5 ,, 10	9 ,, 11	0	3
Swindon - - - - -	1 ,, 11	4 ,, 12	0	3
Nuneaton - - - - -	3 ,, 18	9 ,, 18	1	7
Rugby - - - - -	0 ,, 15	7 ,, 16	0	7
Lincoln - - - - -	0 ,, 16	8 ,, 19	0	7
Berkhamsted - - - -	4 ,, 12	7 ,, 14	0	2
Chelmsford - - - - -	8 ,, 18	12 ,, 18	1	3 (and 2 doubtful)
Hartley Wintney - - -	6 ,, 14	5 ,, 15	1	0
Kenilworth - - - - -	0 ,, 15	1 ,, 14	0	1
Alderley Edge - - - -	2 ,, 15	3 ,, 17	0	1
Wilpshire - - - - -	3 ,, 13	1 ,, 13	2	0
Cambridge - - - - -	2 ,, 13	1 ,, 13	1	0
Coventry - - - - -	0 ,, 19	0 ,, 19	0	0
Consett - - - - - -	1 ,, 8	1 ,, 8	0	0
Buxton - - - - -	0 ,, 18	2 ,, 18	0	2
Halstead - - - - -	0 ,, 7	0 ,, 7	0	0
Stratford-on-Avon - - -	0 ,, 13	2 ,, 13	0	2
	44 out of 247, or 18 per cent.	81 out of 257, or 32 per cent.	6	38

The foregoing table shows the incubator test (carried out as described) to be more lenient than a standard of 2·0 dissolved oxygen absorption in 5 days, by about 14 per cent. Or, to put it differently, while 82 per cent. of the samples examined passed the incubator test, only 68 per cent. passed that for dissolved oxygen absorption. In the great majority of cases the two tests (as defined above) run parallel, but, where they give contrary indications, the 5 days test (on a 2·0 standard) is more severe than the incubator test in the ratio of 38 to 6, or 6 to 1.

An incubator test standard such as that under discussion (*i.e.*, a standard of non-offensive decomposition on incubation of an effluent for 5 days at 27° C.) would thus be less stringent than a standard of 2·0 dissolved oxygen absorption in 5 days at 18° C.; it would allow some effluents to pass which might have a very considerable de-oxygenating action upon the water of a stream.

We consider, therefore, that for purposes of a general standard the incubator test is less to be recommended than the dissolved oxygen absorption test. It might, however, come in usefully as a subsidiary standard in certain cases.

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* The various places are given in the same order in Table XVI. as in Table VIII., though there are rather more samples (*i.e.*, a total of 257 samples in Table XVI. as against 243 in Table VIII.).

TABLE XVII. (TABLES XVII. and XVIII. are discussed on p. 78).

ANALYSIS OF DILUTED SEWAGES AND EFFLUENTS BEFORE AND AFTER A FEW DAYS' INCUBATION AT 18° C. (65° F.).

Sample, place, and date.	Date of analysis.	Dilution (volumes tapwater).	Ammoniacal nitrogen.	Albuminoid nitrogen.	Nitrous nitrogen.	Nitric nitrogen.	"Oxygen absorbed" in 4 hours $\left(\frac{N}{80}\right)$	Dissolved oxygen taken up in 5 days.	Number of days incubated.
EALING sewage (July 25th, 1910), settled overnight and siphoned :—									
Before incubation	July 26th, 1910.	99	0·062	0·015	0·00	0·165	0·123	0·37	7
After ,,	—	—	0·064	0·012	0·00	0·100	0·113	—	—
EALING sewage (July 25th, 1910), settled overnight and siphoned :—									
Before incubation	July 26th, ,,	49	0·129	0·025	0·00	0·125	0·167	0·78 + x	7
After ,,	—	—	0·091	0·016	0·00	0·113	0·123	—	—
*SWINDON effluent (July 27th (?), 1910) :—									
Before incubation	July 28th, ,,	9	0·256	0·035	0·00	0·125	0·174	0·25	5
After ,,	—	—	0·256	0·039	0·00	0·175	0·193	—	—
†ACCRINGTON effluent (July 28th, 1910) :—									
Before incubation	Aug. 2nd, ,,	4	0·025	0·023	0·00	0·400	0·276	{0·18 ‡‡	6
After ,,	—	—	0·007	0·023	0·02	0·330	0·258	0·24	—
‡BURNLEY effluent (August 5th, 1910) :—									
Before incubation	Aug. 8th, ,,	5	0·076	0·027	0·00	0·163	0·188	{0·20 ‡‡	4
After ,,	—	—	0·078	0·022	0·00	0·163	0·177	0·40	—
§HENDON mixed contact and percolation effluent (August 12th, 1910) :—									
Before incubation	Aug. 16th, ,,	4	0·265	0·036	0·00	0·480	0·215	0·70	6
After ,,	—	—	0·136	0·031	0·20	0·360	0·299	—	—
‖STRATFORD effluent (August 11th, 1910) :—									
Before incubation	Aug. 17th, ,,	4	0·044	0·019	0·02	0·380	0·236	{0·18 ‡‡	5
After ,,	—	—	0·006	0·019	0·05	0·365	0·239	0·18	—
¶KENILWORTH final effluent (August 16th, 1910) :—									
Before incubation	Aug. 19th, ,,	4	0·003	0·019	0·00	1·510	0·246	{0·02 ‡‡	5
After ,,	—	—	0·003	0·017	0·00	1·520	0·246	0·03	—
**NUNEATON final effluent (August 16th, 1910) :—									
Before incubation	Aug. 19th, ,,	4	0·141	0·020	0·00	0·220	0·200	{0·26 ‡‡	5
After ,,	—	—	0·102	0·017	0·08	0·170	0·224	0·27	—
††COVENTRY effluent (August 17th, 1910) :—									
Before incubation	Aug. 23rd, ,,	4	0·436	0·026	0·00	0·385	0·193	{0·36 ‡‡	6
After ,,	—	—	0·342	0·026	0·15	0·310	lost	0·37	—
HENDON contact effluent (November 7th, 1910) :—									
Before incubation	Nov. 9th, ,,	9	0·287	0·025	0·00	0·275	0·082	{0·15 ‡‡	5
After ,,	—	—	0·294	0·026	0·08	0·200	0·072	0·13	—
HENDON percolation effluent (November 7th, 1910) :—									
Before incubation	Nov. 10th, ,,	No dilution.	1·536	0·066	0·00	1·08	0·465	0·29	5
After ,,	—	—	1·572	0·068	0·07	1·05	0·384	—	—

* The effluent was opalescent and contained a small quantity of suspended solids.

† This was the ordinary effluent as discharged. It contained about 6 parts suspended solids.

‡ The effluent was opalescent, with little suspended solids. Wormy smell.

§ The contact effluent was turbid, with strong septic smell. The percolation effluent was sparkling. Very little suspended solids.

‖ The effluent was clear and brownish tinted.

¶ The effluent was brown and bright, with appreciable suspended matter. No smell.

** Effluent brownish and rather opalescent. Considerable fine suspended solids. Earthy smell.

†† Very brownish but clear, with much flocculent brown suspended solids.

‡‡ Duplicate estimations.

TABLE XVIII.

Analysis of Table XVII.

Column.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
	Original sample.		Sample after incubation.		Increase or decrease in:—		Ammoniacal nitrogen.			Dissolved oxygen taken up in 5 days.	Nitrate which has disappeared (in terms of oxygen) less nitrite which has been formed.*	Oxygen + nitrate oxygen which has been taken up.†	Oxygen equivalent to the ammoniacal nitrogen in Col. 9.‡	Oxygen taken up by carbonaceous matter.§	Percentage of the total oxygen which has been taken up by carbonaceous matter. ‖
	Nitric nitrogen.	Nitrous nitrogen.	Nitric nitrogen.	Nitrous nitrogen.	Nitric nitrogen.	Nitrous nitrogen.	Original sample.	Sample after incubation.	Increase or decrease in ammoniacal nitrogen.						
No. 1	0·165	—	0·100	—	– 0·065	0	0·062	0·064	+ 0·002	0·37	0·20	0·57	0	0·57	100%
No. 2	0·125	—	0·113	—	– 0·012	0	0·129	0·091	– 0·038	0·78 + x	0·04	0·82 + x	0·06	0·76 + x	93%
No. 3	0·125	—	0·175	—	+ 0·050	0	0·256	0·256	0	0·25	+ 0·15	0·10	0	0·10	40%
No. 4	0·400	—	0·330	0·02	– 0·070	+ 0·02	0·025	0·007	– 0·018	0·21	0·18	0·39	0·03	0·36	92%
No. 5	0·163	—	0·163	—	0	0	0·076	0·078	+ 0·002	0.30 (?)	0	0·30	0	0·30	100%
No. 6	0·480	—	0·360	0·20	– 0·120	+ 0·20	0·265	0·136	– 0·129	0·70	0·02	0·72	0·22	0·50	69%
No. 7	0·380	0·02	0·365	0·05	– 0·015	+ 0·03	0·044	0·006	– 0·038	0·18	+ 0·01	0·17	0·06	0·11	65%
No. 8	1·510	—	1·520	—	+ 0·010	0	0·003	0·003	0	0·03	+ 0·03	0	0	0	0
No. 9	0·220	—	0·170	0·08	– 0·050	+ 0·08	0·141	0·102	– 0·039	0·27	0·01	0·28	0·07	0·21	75%
No. 10	0·385	—	0·310	0·15	– 0·075	+ 0·15	0·436	0·342	– 0·094	0·37	+ 0·03	0·34	0·16	0·18	53%
No. 11	0·275	—	0·200	0·08	– 0·075	+ 0·08	0·287	0·294	+ 0·007	0·14	0·09	0·23	+ 0·01	0·23	100%
No. 12	1·080	—	1·050	0·07	– 0·030	+ 0·07	1·536	1·572	+ 0·036	0·29	+ 0·03	0·26	+ 0·06	0·26	100%

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* The figures in Col. 11 are arrived at by multiplying the figure in Col. 5 by 3, and subtracting from the result the figure in Col. 6 × 1·7, thus:—

Col. 5. $N_2O_5 = N_2 : O_5 = 28 : 80 = 1 : 3$.
Col. 6. $N_2O_3 = N_2 : O_3 = 28 : 48 = 1 : 1{\cdot}7$.

† The figures in this column (12) are got by adding together those in Cols. 10 and 11.

‡ The figures in Col. 13 are got by multiplying those in Col. 9 by 1·7, thus:—

$$2NH_3 + O_3 = 3H_2O + N_2$$
$$N_2 : O_3 = 28 : 48 = 1 : 1{\cdot}7$$

§ The figures in Col. 14 are got by deducting those in Col. 13 from the figures in Col. 12.

‖ The figures in Col. 15 represent the percentage ratios of Col. 14 to Col. 12.

(6) DISSOLVED OXYGEN ABSORPTION IN 5 DAYS AT 18·3° C. (65° F.).[1]

This test has already been very fully discussed, when comparing with it the various other tests treated in this memorandum, so that not a great deal more requires to be said about it.

A further reference may, however, be made here to Table I., p. 64A. This table shows that, in the case of streams receiving sewage liquor or effluent, as regards matter oxidizable by dissolved oxygen (up to at least the equivalent of 1.5 part dissolved oxygen absorption in 5 days), the more of such matter there is present, the greater will be the reduction in unit length of stream. In other words, as might be expected, the aggregate chemical improvement of the water is less when a good than when a bad effluent enters a stream.

That the matter oxidized, when a diluted sewage liquor or effluent is subjected to this test, is mainly carbonaceous matter, is evident from a study of Table XVII., p. 76, where the figures of the double analysis of two diluted sewage liquors and ten diluted effluents (*i.e.*, diluted with tap water in all but the last instance), before and after incubation for 4 to 7 days at 18° C., are given.*

A partial analysis of this table is set out in Table XVIII., p. 77, from which it is seen that there is a diminution in ammoniacal nitrogen in the incubated, as compared with the original, sample in six cases and an increase in one case only (leaving out three samples where the difference showed itself only in the third decimal place). In this last case (No. 12) the actual quantities of ammoniacal nitrogen found were very large, relatively to the difference between them, so that the latter might quite well come within the limit of error of experiment. Under the conditions of experiment, therefore, *i.e.*, in the incubation of somewhat dilute mixtures of sewage liquor or effluent with tap water, there being an excess of dissolved oxgyen present all the time,† no increase, or practically no increase, in ammoniacal nitrogen took place. In five of the six cases which show a diminution in ammoniacal nitrogen there is also a reduction in the oxidized (nitric + nitrous) nitrogen. There is a reduction in the oxidized nitrogen in six cases out of the twelve, an increase in five, and no (permanent) change in this respect in one.

If we take 1 part by weight of nitric nitrogen as approximately equivalent, for purposes of oxidation, to 3 parts of oxgyen, ‡and 1 part of nitrous nitrogen as equivalent to 1·7 parts of oxygen, and if we add or subtract—as the case may be—this equivalent of nitrous and nitric nitrogen to or from the dissolved oxygen taken up on incubation, we get the total amount of oxygen taken up (Table XVIII., Column 12). Deducting from the latter the oxygen necessary to oxidize the ammonia which has disappeared during the incubation, there remains the oxygen which must have been absorbed by the carbonaceous matter. The percentage of the total oxygen taken up which has been thus used by the carbonaceous matter is given in Column 15.

From these figures it is seen that the 5 days' dissolved oxygen absorption test gives in the main a measure of the carbonaceous matter of a sewage liquor or effluent. Broadly speaking, it determines only carbonaceous matter in the case of a sewage liquor, but in the case of an effluent, already well oxidized, the oxygen which the latter uses up in 5 days may be taken more by the ammonia than by the small quantity of unoxidized carbonaceous compounds still present. For ordinary filter effluents the 5 days' dissolved oxygen absorption test may be regarded as measuring carbonaceous matter, for the most part.

It may quite reasonably be asked, however, why should it be considered necessary to extend the dissolved oxygen absorption test over 5 days, instead of being content with a shorter period, say, 48 hours, or even 24 hours ?

Either of these latter, at least the 48 hours' test (we have much fewer data as regards the 24 hours'), if carried out under suitable conditions, would no doubt prove fairly satisfactory also as a standard test. But the main reason, apart from our much larger experience of the 5 days' test, for recommending 5 days as the period to be allowed is that error of experiment may be minimised, by giving sufficient time for a reasonable proportion of the oxidizable matter present in an effluent to be oxidized (*Cf.* Table VIII., p. 68, Columns 2 and 7.) It may be taken broadly that, within the time limits of 1 and 5 days, the possible error of experiment is larger, the shorter the period. Further, although we have not, perhaps, such definite proof of this as might be desired, the absorption of dissolved oxygen by diluted effluents sometimes appears to lag a little at first; in such cases the diluted mixtures are probably at first comparatively poor in available nutrient matter and in bacteria.

Dissolved Oxygen Absorption in 48 Hours.

Table XIX. shows the average figures for dissolved oxygen absorption in 48 hours and in 5 days given by a large number of samples, both of sewage liquor and of effluent. The samples are the same as those already referred to in Table VIII., etc., excepting that in Table XIX. there are slightly fewer.

It will be seen that in the case of the sewages and sewage liquors the variations in ratio of the two tests (48 hours : 5 days) are not at all excessive, the extremes in sixty samples being 1 : 0·93 to 1 : 4·00, while the average ratio works out at about 1 : 1·7.

In the case of effluents, as is to be expected, the ratios show much greater variations, the extremes being 1 : 0·86 to 1 : 18·0, while the average ratios vary between 1 : 1·82 and 1 : 5·94. The very low ratios are no doubt fallacious, the 48 hours' figure for those samples being very small; dilution with two volumes of tap-water had evidently been sufficient to make the absorption of oxygen very slow at the start. Speaking generally, the ratio is highest in the case of poorly oxidized effluents and lowest in the case of well oxidized ones, but the sequence in the table is by no means consistent in this respect.

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[1] The reasons for selecting this temperature for the test are given in Part II., Section 2 of this Appendix, p. 94. It should be added here, however, that during very warm weather the temperature of the cold-water incubator rose at times several degrees higher than this, so that the figures given for dissolved oxygen absorption are not all strictly accurate for this temperature, though they may practically be taken as being so. If the test is to be employed for purposes of a standard, it may be necessary to use in summer an incubator provided with an ice chamber.

* This table would have been improved if determinations of the total nitrogen (by Kjeldahl) had also been made.

† In No. 2 the oxygen had become exhausted.

‡ *Cf.* Fifth Report, App. IV., p. 12.

TABLE XIX.

Showing Average Figures for Dissolved Oxygen Absorption in 48 Hours and in 5 Days, and their Ratios to one another.

Place.	Dissolved oxygen absorption in— 48 hours.	5 days.	Extreme ratios (48 hours = 1).	Average ratios.	Number of samples examined.
	*Group I.—Sewages and Tank Liquors.**				
Malton - - - - -	27·1	41·6	1 : 0·93 — 1 : 2·07	1 : 1·55	13
Huntingdon - - -	28·4	43·1	1 : 1·31 — 1 : 1·93	1 : 1·59	7
St. Neots - - - -	25·4	32·9	1 : 1·29 — 1 : 2·28	1 : 1·82	12
Pickering - - - -	13·0	24·5	1 : 1·23 — 1 : 4·00	1 : 1·99	11‡
Wye - - - - -	12·6	18·9	1 : 1·22 — 1 : 2·05	1 : 1·56	6
Barnoldswick - - -	8·9	14·6	1 : 1·00 — 1 : 2·95	1 : 1·83	11
Ollerton - - - -	4·3	9·9	1 : 1·83 — 1 : 2·63	1 : 2·23	2
	Group II.—Effluents.†				
Tiverton - - - -	2·70	4·57	1 : 1·24 — 1 : 2·70	1 : 1·82	11
Middleton - - - -	1·56	3·94	1 : 1·59 — 1 : 6·86	1 : 2·87	11
Swindon - - - -	0·86	2·72	1 : 1·38 — 1 : 3·26	1 : 2·23	10
Nuneaton - - - -	0·76	2·46	1 : 1·37 — 1 : 6·54	1 : 3·76	17
Rugby - - - -	0·39	2·01	1 : 2·27 — 1 : 11·67	1 : 5·94	15
Lincoln - - - -	0·58	1·95	1 : 1·11 — 1 : 5·33	1 : 3·29	18
Berkhamsted - - -	0·92	2·09	1 : 1·22 — 1 : 3·82	1 : 2·25	12
Chelmsford - - -	0·97	1·74	1 : 1·10 — 1 : 8·57	1 : 2·74	18
Hartley Wintney - -	0·75	1·68	1 : 1·06 — 1 : 9·67	1 : 3·54	12
Kenilworth - - -	0·51	1·33	1 : 1·80 — 1 : 18·0	1 : 3·93	14
Alderley Edge - - -	0·43	1·28	1 : 1·48 — 1 : 4·22	1 : 2·30	15
Wilpshire - - - -	0·58	1·16	1 : 1·26 — 1 : 3·05	1 : 2·04	11
Cambridge - - -	0·65	1·15	1 : 1·33 — 1 : 2·97	1 : 1·96	11
Coventry - - - -	0·38	1·00	1 : 1·62 — 1 : 18·0	1 : 4·45	19
Consett - - - -	0·34	0·90	1 : 1·37 — 1 : 8·92	1 : 3·86	8
Buxton - - - -	0·37	1·01	1 : 1·52 — 1 : 10·0	1 : 3·38	17
Halstead - - - -	0·29	0·79	1 : 1·22 — 1 : 8·83	1 : 4·21	7
Stratford-on-Avon - -	0·29	0·63	1 : 0·86 — 1 : 4·38	1 : 2·69	9

As illustrative of the average figures for the 48 hours' and 5 days' tests given by the same type of percolating filter effluent, with and without its suspended solids, we may quote from the Accrington experiments, Nos. IV. and V. (Fifth Report, Appendix IV., pp. 67 and 70). The dilutions given were usually 2 volumes of tap water for the 48 hours' test, though in some cases, 4 and even 9 volumes; for the 5 days' test the dilution was usually 4 volumes, but in some cases 9, and even 19 volumes. In this case the average ratios of the two tests are comparatively even, though here again the extremes are widely apart.

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* The dilutions for sewage liquors were 1 + 39 to 1 + 199 (mostly 99 or 199).

† For all the effluents, other than effluents of poor quality, the dilutions were 1 + 2 vols. and 1 + 4 vols. tap water.

‡ Omitting one ratio of 1 : 4·0, the average ratio for the remaining ten samples is 1 : 1·76.

Accrington Experiments.

	Percolating filter effluent from strong septic tank liquor.		Percolating filter effluent from weak septic tank liquor.	
	Original effluent.	Paper-filtered effluent.	Original effluent.	Paper-filtered effluent.
Page 67 (Experiment IV.).				
Dissolved oxygen absorption at 18° C.* :—				
In 48 hours - - - - - - -	0·67 (8)	0·19 (8)	0·61 (8)	0·21 (8)
In 5 days - - - - - - -	2·56 (8)	0·59 (9)	1·66 (8)	0·48 (9)
Average ratio of 48 hours' to 5 days' tests -	1 : 3·8	1 : 3·1	1 : 2·7	1 : 2·3
Page 70 (Experiment V.).				
In 48 hours - - - - - - -	2·46 (13)	0·89 (13)	0·97 (13)	0·57 (13)
In 5 days - - - - - - -	6·68 (13)†	2·31 (13)	2·82 (13)	1·16 (13)
Average ratio of 48 hours' to 5 days' tests -	1 : 2·7	1 : 2·6	1 : 2·9	1 : 2·0

It is noteworthy that the average ratio is invariably higher in the case of the paper-filtered than of the original effluent (*i.e.*, with suspended solids included), the average ratios in the original effluents ranging from 1 : 2·7 to 1 : 3·8, and in the paper-filtered from 1 : 2·0 to 1 : 3·1.

The 48 Hours' Test. Dissolved Oxygen Absorption by Undiluted and Diluted Effluents.

In Table XX. are given some comparative estimations, made for the Commission by six sewage authorities, of dissolved oxygen absorption in 48 hours at 18° C., (*a*) by effluent diluted with 2 volumes of tap water; and (*b*) by the undiluted effluent, after the latter had been oxygenated by shaking. Since the maximum amount of oxygen available for absorption in the latter case could not exceed about 0·8 to 0·9 part, the comparison in the above table is necessarily restricted to effluents of fair to good quality—effluents which would very rarely exceed a figure of 2·0 for dissolved oxygen absorption in 5 days.

If this table be examined, it will be seen that in the two cases where considerable numbers of effluents were tested—Croydon and Huddersfield—the first effluent contained only 0·8 part of suspended solids, while the second was paper-filtered. In both, the average absorption of dissolved oxygen in 48 hours was the same (or practically the same), whether the effluent was tested undiluted or diluted with two volumes of tap water. The number of determinations made on the various other effluents was very small (the suspended solids ranging from 0·0 to 1·5) and the actual differences in the figures for dissolved oxygen absorptions were very small also, excepting with the effluents from Burnley and Bradford.

Taking the results as a whole, there was little difference in the degree of absorption, whether the effluent was undiluted or diluted with two volumes of water, but on the whole a slightly higher figure was obtained with the diluted sample. (*Cf.* also Section 2, Addenda A, C, and D, pp. 100–102).

TABLE XX.

SHOWING COMPARATIVE AVERAGE FIGURES FOR DISSOLVED OXYGEN ABSORPTION IN 48 HOURS AT 18° C, GIVEN BY (*a*) EFFLUENT DILUTED WITH 2 VOLUMES OF TAP WATER, AND (*b*) UNDILUTED EFFLUENT, SHAKEN UP TO ENSURE INITIAL AERATION.

Place.	Suspended solids (average).	Dissolved oxygen absorption in 48 hours by—		Ratio of absorptions by diluted and undiluted (diluted = 1).	Number of samples tested.
		Diluted effluent.	Undiluted effluent.		
Burnley - - - - - - -	0·6	0·86	0·43	1 : 0·50	9
Bradford - - - - - -	1·2	0·45	0·30	1 : 0·66	7
Croydon - - - - - - -	0·8	0·27	0·25	1 : 0·93	21
Huddersfield - - - - -	2·1	0·45	0·42	1 : 0·93	3
Chester - - - - - - -	1·5	0·63	0·64	1 : 1·02	3
Chester (paper-filtered) - - -	—	0·27	0·23	1 : 0·85	2
Huddersfield (paper-filtered) - -	—	0·47	0·47	1 : 1·0	25
Bury (paper-filtered) - - -	—	0·54	0·48	1 : 0·89	6

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* At the time those estimations were made, the diluting tap water was not previously warmed to 18° C., and then shaken up.

† Oxygen exhausted in two cases.

The 24 Hours' Dissolved Oxygen Absorption Test.

As already stated, we have much less experience as regards the 24 hours' than as regards the 5 days' test. Still, the data available merit some discussion.

In Table XXI. are to be found the figures for dissolved oxygen absorption in 24 hours and in 5 days yielded by a fair number of sewages and tank liquors. The dilutions given were appropriate to the strengths of the liquors, excepting in the case of the Pickering samples, which were much over-diluted.

From this Table it will be seen that the average ratio-figures of the two tests—24 hours : 5 days—may be taken for sewages and sewage liquors as 1 : 2 to 1 : 3. The average ratio in the case of septic tank liquors is rather higher than with sewages or precipitation liquors, an indirect proof that the septic tank tends to convert some of the less easily fermentible compounds of sewage into compounds more amenable to bacterial oxidation.

TABLE XXI.

Showing, for Sewage and Tank Liquors, the Dissolved Oxygen Absorption at 18° C. in 24 Hours and in 5 Days.

Place.	Dissolved oxygen absorption in—		Ratio of the tests (24 hours : 5 days).
	24 hours.	5 days.	
Sewages.			
Huntingdon 114 K	10·5	29·0	1 : 2·8
Malton 174 K	20·2	55·4	1 : 2·7
„ 294	19·3	39·7	1 : 2·1
„ 258 K	17·3	49·6	1 : 2·9
Pickering 177 K	8·5	28·0	1 : 3·3
„ 300	6·2	12·7	1 : 2·1
	Average ratio		1 : 2·7
Septic Tank Liquors.			
Exeter (Main works)	8·6	20·7	1 : 2·4
„ (St. Thomas)	2·3	5·0	1 : 2·2
Andover	9·7	21·3	1 : 2·2
Ilford	3·2	8·9	1 : 2·8
Accrington	2·6	7·7	1 : 2·5
St. Neots	13·3	24·0	1 : 1·8
„ 218	12·2	22·3	1 : 1·8
„ 290	21·9	40·6	1 : 1·9
	Average ratio		1 : 2·2
Precipitation Liquors.			
Glasgow (Dalmuir)	0·9	2·3	1 : 2·6
„ (Dalmarnock)	2·4	7·2	1 : 3·0
„ (Shieldhall)	2·7	6·6	1 : 2·4
Normanton	4·7	13·8	1 : 2·9
Royton	12·2	41·7	1 : 3·5
	Average ratio		1 : 2·9

Table XXII. gives the figures for dissolved oxygen absorption in 24 hours, 48 hours and 5 days, yielded by 18 samples of effluent from different places. These have been selected from a much larger number, in order to exclude all samples which took up less than 20 per cent. of the oxygen originally present in the mixture of effluent and tap water, *i.e.*, to exclude cases of marked over-dilution. The dilution given for the 24 hours' test was 2 volumes of tap water in eleven cases, 4 volumes in five cases, and 9 volumes in two cases. The effluents in this table are, therefore, effluents of poor quality, as a rule. Hence, the ratios of the 24 hours' test to the 48 hours' and (especially) the 5 days' tests will tend to be higher than if the effluents had been of better class.

The main conclusions to be drawn from this table—so far as it goes—are, we think, that, given suitable dilutions, effluents of about average quality will show ratios of something like:—

24 hours : 48 hours - - - - 1 : 1·8
24 hours : 5 days - - - - 1 : 3·0
48 hours : 5 days - - - - 1 : 1·8

TABLE XXII.

SHOWING, FOR EFFLUENTS OF MEDIUM TO POOR QUALITY, THE DISSOLVED OXYGEN ABSORPTION AT 18° C., IN 24 HOURS, 48 HOURS, AND 5 DAYS.

Place.	Dissolved oxygen absorption.			Ratio— 24 hours : 48 hours.	Ratio 24 hours : 5 days.	Ratio— 48 hours : 5 days.
	24 hours.	48 hours.	5 days.			
Tiverton - - - -	0·77	1·56	2·28	1 : 2·0	1 : 2·9	1 : 1·4
„ - - - - -	1·60	4·20	5·20	1 : 2·6	1 : 3·3	1 : 1·2
Middleton - - - -	1·04	1·87	2·97	1 : 1·8	1 : 2·9	1 : 1·6
Swindon - - - -	0·81	2·07	7·00	1 : 2·6	1 : 8·6	1 : 3·4
Nuneaton - - - -	0·79	1·85	3·20	1 : 2·3	1 : 4·1	1 : 1·7
Berkhamsted - - -	0·60	1·15	2·41	1 : 1·9	1 : 4·0	1 : 2·1
Chelmsford - - -	1·70	2·00	2·72	1 : 1·2	1 : 1·6	1 : 1·4
„ - - - - -	0·80	1·47	3·73	1 : 1·8	1 : 4·6	1 : 2·5
Hartley Wintney - -	0·54	0·96	1·46	1 : 1·8	1 : 2·7	1 : 1·5
Kenilworth - - -	1·27	2·24	6·95	1 : 1·8	1 : 5·5	1 : 3·1
Alderley Edge - -	0·53	0·95	1·75	1 : 1·8	1 : 3·3	1 : 1·8
„ „ - - -	0·52	0·72	1·08	1 : 1·4	1 : 2·1	1 : 1·5
Wilpshire - - - -	0·48	0·87	1·65	1 : 1·8	1 : 3·4	1 : 1·9
„ - - - - -	0·49	0·79	1·47	1 : 1·6	1 : 3·0	1 : 1·9
Coventry - - - -	0·51	?	0·75	?	1 : 1·5	?
„ - - - - -	0·53	0·48	1·22	1 : 0·9 (?)	1 : 2·3	1 : 2·5
Consett - - - -	1·71	2·84	4·00	1 : 1·7	1 : 2·3	1 : 1·4
Stratford-on-Avon - -	1·05	1·80	3·35	1 : 1·7	1 : 3·2	1 : 1·9
		Average ratio	-	1 : 1·8	1 : 3·4	1 : 1·9

A good many estimations of dissolved oxygen absorption in 24 hours by percolating filter effluents, with and without their suspended solids, are to be found in the account of the Accrington experiment, No. I. (Fifth Report, Appendix IV., p. 55*a*). The dilutions given were 2 volumes tap water for the 24 hours' test and either 2 or 4 volumes for the 5 days' test. Relatively few of those samples (especially of the whole samples with suspended solids included) were submitted to the 5 days' test, and hence the data for comparison are meagre, So far as they go, however, the figures are:—

Accrington Experiment I.

	Percolating filter effluent from strong tank liquor.		Percolating filter effluent from weak tank liquor.	
	Original effluent.	Paper-filtered effluent.	Original effluent.	Paper-filtered effluent.
Dissolved oxygen absorption at 18° C.—				
In 24 hours - - - - - -	—	0·29 (6)	0·40 (3)	0·23 (6)
In 5 days - - - - - -	—	1·39 (6)	1·54 (3)	0·82 (6)
Average ratio of 24 hours' to 5 days' tests -	—	1 : 4·7	1 : 3·9	1 : 3·6
	Secondary contact effluent from strong tank liquor.		Secondary contact effluent from weak tank liquor.	
Dissolved oxygen absorption at 18° C.—	Original effluent.	Paper-filtered effluent.	Original effluent.	Paper-filtered effluent.
In 24 hours - - - - - -	—	0·50 (4)	0·30 (3)	0·33 (4)
In 5 days - - - - - -	—	1·88 (4)	1·00 (3)	1·38 (4)
Average ratio of 24 hours' to 5 days' tests -	—	1 : 3·8	1 : 3·3	1 : 4·2

Dissolved Oxygen taken up by River Waters of good quality.

Determinations, made in each case in duplicate, of dissolved oxygen absorption at 18° C. in 1, 2, 3, 4 and 5 days by three river waters of good to high quality, gave the following figures (which are also plotted in Diagram E.):

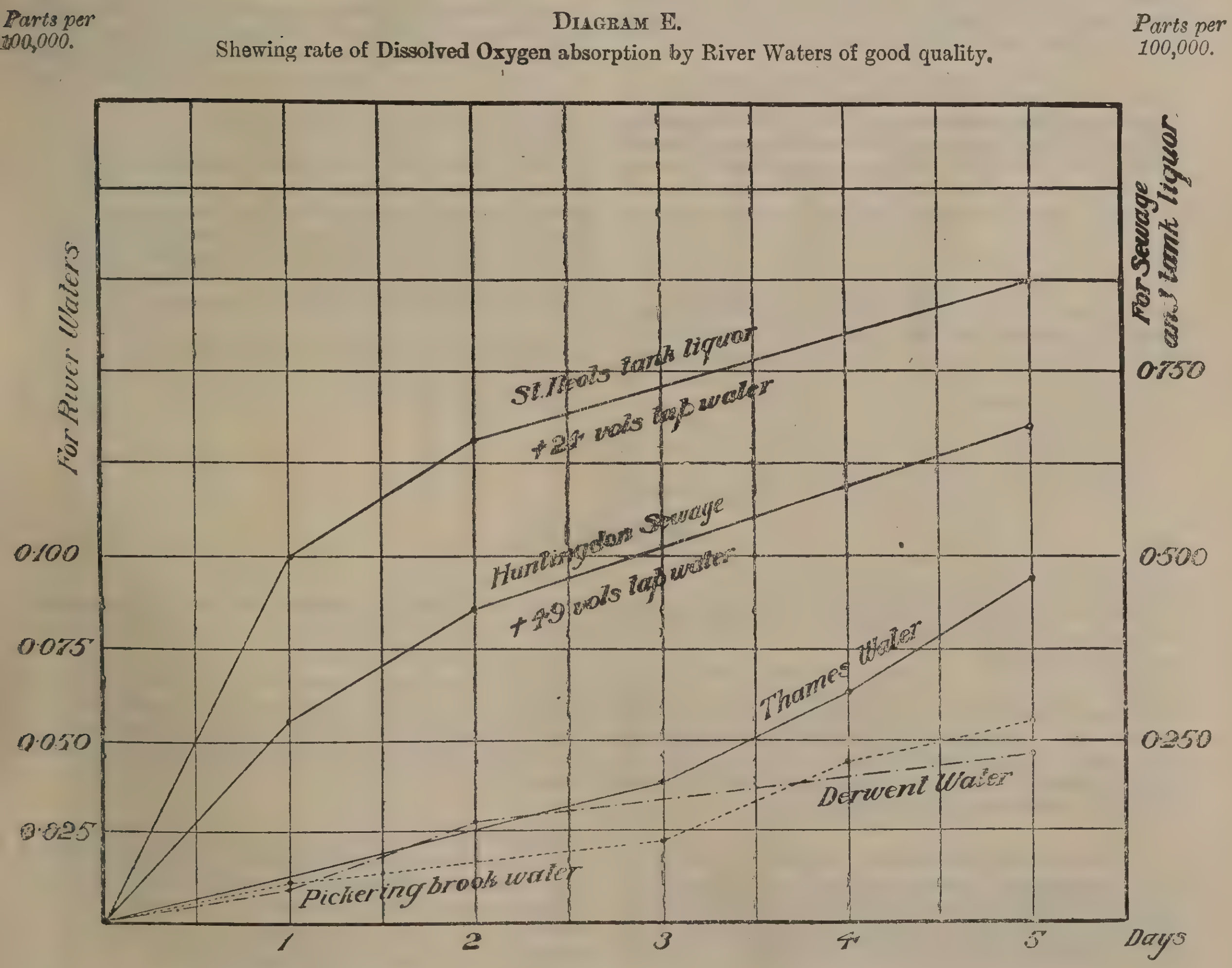
Parts per 100,000

Date of analysis, 1912.	River Thames at Hampton.* March 4th.	Pickering Beck at Pickering. April 19th.	River Derwent at Consett. May 9th.
Dissolved oxygen absorption in—			
1 day - - - - - - - -	0·014	0·013	0·012
2 days - - - - - - -	0·025	—	0·027
3 " - - - - - - -	0·039	0·023	—
4 " - - - - - - -	0·065	0·046	0·042
5 " - - - - - - -	0·094	0·056	0·047

* Sample drawn when the river was high and the current fast, after heavy rain.

DIAGRAM E.

Shewing rate of Dissolved Oxygen absorption by River Waters of good quality.



NOTE.—The scale for the diluted sewage and the tank liquor is one-fifth of that for the river waters.

The above figures with the corresponding Diagram E. (which includes also typical curves of two diluted sewage liquors) show that, in the case of very pure river waters, such as those from Pickering and Consett, taking up only about 0·05 part dissolved oxygen in 5 days, the "absorption curve" for 1 to 5 days is almost a straight line. In the Thames water, which though of good quality chemically was not of such high class, the absorption rose materially after the third day.

In the case of a diluted sewage, tank liquor or poor effluent, the corresponding "curve" is at first somewhat steep and then tends to flatten out until the nitrification stage is reached, when it again rises rapidly. After nitrification is complete, there is almost no more oxidation to be done, and the curve becomes nearly a straight line, *i.e.*, it has now reached the stage shown by the pure river waters of Pickering and Consett. In such waters only traces of ammonia and of fermented matters are present, and the oxidation of the latter apparently proceeds at a very even pace from the first day onwards, *i.e.*, the ratio of the two tests—24 hours : 5 days—is at least 1 : 4 and possibly 1 : 5.

The bacterial oxidation of the impurity of a diluted sewage liquor in 1 to 5 days means oxidation of readily fermentible carbonaceous matter; the oxidation in the case of a pure river water means oxidation of the organic products from a previous "carbon" fermentation of polluting organic matters, and these products are highly stable substances under the natural conditions to which river waters are subjected *; in the case of a diluted effluent of average quality, while the oxidation is mainly one of carbonaceous matter, it may also include nitrification, *i.e.*, (rapid) oxidation of ammonia.

The three cases are thus broadly distinct from one another and the consideration of them affords a probable explanation of the observed fact that the average ratio of the two tests—24 hours : 5 days—is not always in the case of effluents intermediate between the corresponding ratio for sewage liquors, on the one hand, and for pure waters on the other.

Mr. E. H. Richards has pointed out that the ratio of the 24 hours' to the 5 days' test may be applied to a polluted river water of unknown origin, with a view to ascertaining whether it has been polluted by a sewage or tank liquor, on the one hand, or by a fairly well purified effluent on the other. This has been found to work well in the case of waters artificially polluted by sewage and effluent, respectively, but we have not yet got many data from naturally polluted samples. The subject is under investigation.

We ourselves had previously applied the ratio of albuminoid nitrogen to dissolved oxygen absorption in 5 days for the same purpose (*Cf.* Table VIII, p.68), and this also answered well with artificially polluted waters, but it is probably less delicate than the ratio of 24 hours : 5 days. The point requires further investigation.

If the 24 hours' dissolved oxygen absorption test is to be made use of, it should preferably be done upon the undiluted effluent, warmed up to 18° C., and then shaken vigorously, to ensure good oxygenation. The effluent would then contain about 0·8 to 0·9 part of oxygen in solution per 100,000. An effluent taking up 2 parts of oxygen from water in 5 days would probably take up about 0·5 to 0·7 parts in 24 hours, consequently there would be a sufficient reserve of oxygen for it to draw upon.

Just as the "oxygen absorbed" from permanganate test, at once or in 3 minutes, is of value when taken in conjunction with the "oxygen absorbed" in 4 hours, so may the 24 hours' dissolved oxygen absorption test be made of value, in conjunction with the 5 days' test. The 24 hours' and 5 days' tests, taken together, might give a better indication of the quality of an effluent than the 5 days' test alone.

It has, however, to be borne in mind that any substance of an inhibitory character present in an effluent would tend to lower the ratio of the 24 hours' to the 5 days' tests (and even of the 48 hours' to the 5 days'), by keeping the first figure low. This constitutes an additional argument in favour of the 5 days' test, for purposes of a standard, as against either the 24 or the 48 hours'.

It might conceivably (though very improbably) happen that an effluent, sufficiently sterilised (*e.g.*, by lime) to prevent any appreciable absorption of oxygen from water even in 5 days, might come under purview as regards a standard. In such a case the permanganate absorption figures, supplemented by the other ordinary figures of analysis, would quickly explain the anomaly.

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* *Cf.* Adeney, Appendix VI. to Fifth Report, p. 44.

SUMMARY.

It is hardly possible to summarize the foregoing paper within short compass, but a few of its more salient points may be recapitulated.

The self-purification of a moderately polluted river water is well exemplified by the observations made on that stretch of the Warwickshire Avon from above the Rugby effluent outfalls to just above the outfalls at Coventry, a distance of some 13 miles.

Laboratory experiments have confirmed the taking up of the nitrogen of ammonia and nitrate from polluted water by river plants and algæ, while they also indicate that an alga may prefer to assimilate its nitrogen in the form of ammonia rather than of nitrate.

Although the figure for ammoniacal nitrogen may afford the most delicate chemical index of recent sewage pollution, it is less to be relied on as indicating the polluting power of an effluent than the dissolved oxygen absorption in 5 days (*Cf.* also Diagram C.).

The determination of "oxygen absorbed" from permanganate or of albuminoid nitrogen gives in each instance a less correct measure of the more readily fermentible matter remaining in an effluent than does the "5 days" test.

The incubator test (incubation for 5 days at 27° C. (80° F.)) is rather less stringent than a standard of 2·0 dissolved oxygen absorption in 5 days. The incubator test might, however, come in usefully as a subsidiary standard in certain cases.

The 5 days dissolved oxygen absorption test gives a measure of the carbonaceous matter of a sewage liquor and, in the main, of the carbonaceous matter of an average effluent; in the case of an already well oxidized effluent, it may, in part, measure ammonia as well as carbonaceous matter.

Of the tests usually applied in the examination of sewage liquors and effluents, the determination of the dissolved oxygen absorption in 5 days at 18·3° C. (65° F.) affords, on the whole, a better index than any other single test of the effect which such liquors or effluents will exert on the water of a stream. For this reason we consider that, taken in conjunction with the determination of suspended solids, it constitutes the best practical test for purposes of a standard for effluents.

ADDENDUM I. TO SECTION 1.

The Disappearance of Ammonia and Nitrate from Tap Water (non-sterile) in which Aquatic Plants and Algæ were placed.

The ammonia was added as chloride of ammonium and the nitrate, other than that naturally present in the water, as potassic nitrate. In every case the water was protected against dust.

Experiment 1.

Weed No. 4, Duckweed (*Lemna Minor*). Tap water containing 0·50 part ammoniacal nitrogen and 0·24 nitric nitrogen per 100,000, in which some of this weed was placed, showed after 7 days:—ammoniacal nitrogen 0.15 and nitric nitrogen 0.20. The water was then clear and odourless.

The same weed took up practically no nitrate in two days from tap water containing 0·65 part nitric nitrogen, but at the end of 7 days the nitric nitrogen was reduced to 0·38.

These results appear to indicate that the duckweed takes up ammonia rather rapidly, and nitrate only when the supply of ammonia begins to be deficient.

Experiment 2.

No. 6. Alga (*Lemanea Mamillosa*).—Portions of this alga were kept, in diffused daylight, in *slowly moving* streams of the nutrient waters, the water passing from a reservoir into a glass channel containing the alga, where it maintained a constant depth of about 1 inch, and from the channel into a receiver. When the reservoir became nearly empty it was filled up again from the receiver. The vessels were protected against dust.

Tap water containing 0·50 part ammoniacal nitrogen per 100,000 and 0·24 part nitric nitrogen showed no change in 11 days, excepting that 0·04 of the ammoniacal nitrogen had been oxidized to nitrite. After that the ammoniacal nitrogen decreased to 0·16 (in 17 days), and the nitrate was entirely converted to nitrite; but those later changes in the solution were probably induced by a fresh algal growth which made its appearance in the reservoir, and which only became marked after the eleventh day.

From tap water containing 0·72 part nitric nitrogen and a mere trace of ammonia, the alga took up practically no nitrate. At the end of 13 days the solution contained:—

Ammoniacal nitrogen - - - 0·02
Nitrous nitrogen - - - - 0·03
Nitric nitrogen - - - - 0·65 = 0·70

No growth was in this case observed in the reservoir.

The conclusion therefore seems justified that, when tested, this alga had already reached a stage of growth at which it took up, practically, neither ammonia nor nitrate.

It may be added that 5 grammes of wet drained weed were taken for each of the two experiments of No. 6. The residual weeds were not weighed wet at the end of the experiment, but were dried on the top of a hot-air oven. By an oversight they remained there for about two months, when their weights were found to be:—

Residual weed from the ammonium chloride solution - - - 0·82 gramme.
Residual weed from the nitrate solution - - - - - 0·50 „

Experiment 3.

Alga No. 7a. (*Vaucheria Sp*?).—This experiment was carried out in the same way as the preceding one. Two portions of 5 grammes each of the drained and gently squeezed alga were taken, and 4,000 c.c. each of solutions of ammonium chloride and potassic nitrate in tap water. The alga was well cleansed from adhering larvæ and worms, but considerable numbers of these developed in the course of the experiment.

Table A shows the changes which the ammonia and nitrate in solution respectively underwent.—

It is seen from Table A. that the ammonia of the ammonium chloride solution had disappeared after about 17 days, at which time the nitrate was at its maximum. After two months (June and July) the total combined nitrogen in the water had been reduced by about one-half.

The nitrate solution never developed more than traces of ammonia, and in this case the nitrite reached its maximum in 13 days. After two months the total combined nitrogen in the water had been reduced by about one-third.

Experiment 4.

Alga No. 7a *continued*.—This experiment was carried out in the same way and with the same portions of (washed, drained and gently squeezed) alga, now weighing 5.9 and 8.0 grammes, respectively, that had been used in Experiment 3, but fresh solutions of ammonium chloride and potassic nitrate were taken.

Table B. shows the variations in composition of the two solutions during the experiment.

In Experiment 4 the ammonium chloride solution lost its ammonia in about a month; the nitrite reached its maximum (0·07 nitrous nitrogen) in 12 days; and the nitrate increased by one-half in 19 days, after which it remained almost stationary. In the eight weeks during which the experiment lasted, the total nitrogen of the ammonium chloride solution had diminished by one-half while the alga had gained nearly 60 per cent. in weight.

The nitrate solution only developed traces of ammonia and never showed any nitrite, while the nitrate decreased by about one-half; the alga gained 40 per cent. in weight. So far as could be observed, there were no larvæ or worms, present during this experiment.

Experiment 5.

Alga No. 7a *continued*.—This experiment was carried out similarly to Experiments 3 and 4, with fresh solutions, and the results are given in Table C.

From this table it is seen that the ammonium chloride solution lost its ammonia after two months; no nitrite was found in the water at any time; and the nitrate reached its maximum after three months. In the four months which elapsed between the first and last analyses, the total nitrogen in the water had diminished by two-fifths, while the alga (in 6 months, *i.e.*, from Sept. 26th, 1912, to April 4th, 1913) had gained 25 per cent. in weight.

The nitrate solution developed practically no ammonia and no nitrite, while the nitrate remained constant for the first fortnight and only diminished by about one-seventh in four months. The alga (in 6 months) lost about 30 per cent. in weight (rather less).

A "Blank" experiment, carried out with a solution of ammonium chloride in tap water in a clean channel (containing no alga) showed only a slight nitrification of the ammonia in three and a half months (October, 1912, to January, 1913), during which the average air temperature of the room was 50·4° F. (37·5° to 59·5° F.), and a very slight increase in total nitrogen.

Provisional Conclusions.

Referring more particularly to Experiments 3, 4 and 5, and making no attempt here to trace the mechanism of the complex changes taking place in the solutions, supporting as these did vegetable, bacterial and some animal life, the broad fact remains that both the ammonia and the nitrate solutions ultimately became much poorer in combined nitrogen, only nitrate remaining in them. Further, although the experimental results are not conclusive on the point, we think the indications are that the alga takes up ammonia directly, *i.e.*, without waiting for it to become oxidized to nitrate—indeed, that it prefers to assimilate its nitrogen in the form of ammonium salts. If time permits, we hope to carry this work a little further.

EXPERIMENT 3.—TABLE A, SHOWING THE VARIATIONS IN AMOUNT OF AMMONIA, NITRITE AND NITRATE.

Alga No. 7A. 1912.	June 4th.	June 5th.	June 6th.	June 8th.	June 11th.	June 13th.	June 17th.	June 21st.	June 25th.	July 4th.	August 1st.	
Ammonium chloride solution.		*Parts per 100,000.*						*Analyses done on the paper-filtered samples.*				
Ammoniacal nitrogen -	0·50	0·44	0·47	0·45	0·38	0·24	0·01	0·00	0·00	0·00	0·00	Weight of alga at start (drained and gently squeezed), 5·0 grammes.
Nitrous ,, -	0·00	0·00	Trace	0·21	0·25	0·20	0·42	0·15	0·05	0·00	0·00	Weight of alga at end, 5·9 grammes. Increase in weight, 0·9 grammes.
Nitric ,, -	0·22	0·22	0·26	0·00	0·00	0·00	0·20	0·38	0·39	0·61	0·26	Initial volume of ammonium chloride solution, 4,000 c.c.
	*0·72	0·66	0·73	0·66	0·63	0·44	0·63	0·53	0·44	0·61	0·26	Final volume, 2,800 c.c. *Note.*—Fully 100 c.c. had to be used for each analysis.
Potassic nitrate solution.												Weight of alga at start (drained and gently squeezed), 5·0 grammes.
Ammoniacal nitrogen -	0·00	0·01	0·00	0·00	0·03	0·04	0·01	0·00	0·00	0·00	0·00	Weight of alga at end, 8·0 grammes. Increase in weight, 3·0 grammes.
Nitrous ,, -	0·00	0·00	0·02	0·08	0·18	0·25	0·13	0·10	0·08	0·00	0·00	*N.B.*—This alga got rather more light than the other portion.
Nitric ,, -	0·72	0·72	0·38 (?)	0·52	0·45	0·41	0·56	0·44	0·57	0·53	0·39	Initial volume of nitrate solution, 4,000 c.c.
	*0·72	0·72	(?)	0·60	0·66	0·70	0·70	0·54	0·65	0·53	0·39	Final volume, 2,825 c.c.

* These totals do not include either the albuminoid or the total organic nitrogen, as the volume of liquid available did not allow of either estimation being made with accuracy. A determination of albuminoid nitrogen (on 250 c.c.), made at the close of the next experiment, No. 4, gave the figure 0.013. The total organic nitrogen in the waters of this experiment and of the two following, therefore, amounted in all probability to something like 0.03 part per 100,000.

EXPERIMENT 4.—TABLE B, SHOWING THE VARIATIONS IN AMOUNT OF AMMONIA, NITRITE AND NITRATE.

Alga No. 7A—*cont.* 1912.	August 2nd.	August 14th.	August 21st.	August 28th.	September 4th.	September 12th.	September 25th.	
Ammonium chloride solution.	*Parts per* 100,000.			*Analyses done on the paper-filtered samples.*				
Ammoniacal nitrogen - -	0·44	0·19	0·08	0·03	0·01	0·00	0·00	Weight of alga at start (drained and gently squeezed), 5·9 grammes.
Nitrous ,, - -	0·0	0·07	0·02	Trace	Trace	0·0	0·0	Weight of alga at end (drained and gently squeezed), 8·2 grammes.
Nitric ,, - -	0·24	0·23	0·37	0·39	0·34	0·39	0·35	Increase in weight, 3·3 grammes.
	0·68	0·49	0·47	0·42	0·35	0·39	0·35	Initial volume of ammonium chloride solution, 4,000 c.c. Final volume, 3,106 c.c.
Potassic nitrate solution.								
Ammoniacal nitrogen - -	—	0·00	0·01	0·01	0·02	0·00	0·00	Weight of alga at start (drained and gently squeezed), 8·0 grammes.
Nitrous ,, - -	0·0	0·0	0·0	0·0	0·0	0·0	0·0	Weight of alga at end (drained and gently squeezed), 11·1 grammes.
Nitric ,, - -	0·59	0·50	0·47	0·43	0·39	0·31	0·31	Increase in weight, 3·1 grammes.
	0·59	0·50	0·48	0·44	0·41	0·31	0·31	Initial volume of nitrate solution, 4,000 c.c. Final volume of nitrate solution, 3,140 c.c.

EXPERIMENT 5.—TABLE C, SHOWING VARIATIONS IN AMOUNT OF AMMONIA, NITRITE AND NITRATE.

Alga No. 7A—*cont.* 1912.	September 26th.	October 3rd.	October 12th.	October 28th.	November 14th.	December 23rd.	1913. January 28th.	
Ammonium chloride solution.	*Parts per* 100,000.							
Ammoniacal nitrogen - -	0·43	0·37	0·22	0·08	0·05	0·0	0·0	Weight of alga at start, on September 26th, 1912, (drained and gently squeezed), 8·2 grammes.
Nitrous ,, - -	0·0	0·0	0·0	0·0	0·0	0·0	0·0	Weight of alga on April 4th, 1913, 10·3 grammes.
Nitric ,, - -	0·15	0·19	0·29	0·25	0·35	0·45	0·35	Increase in weight, 2·1 grammes.
	0·58	0·56	0·51	0·33	0·40	0·45	0·35	Initial volume of ammonium chloride solution, 4,000 c.c.
Potassic nitrate solution.								Final volume of ammonium chloride solution.† Average temperature from October 17th, 1912, to April 4th, 1913 (37·5° to 59·5°) = 50·3°F.
Ammoniacal nitrogen - -	0·00	0·01	0·01	0·0	0·0	0·0	0·0	Weight of alga at start (drained and gently squeezed), 11·1 grammes.
Nitrous ,, - -	0·0	0·0	0·0	0·0	0·0	0·0	0·0	
Nitric ,, - -	0·58	0·58	0·60	0·44	0·46	0·49	0·50	Weight of alga at end (April 4th, 1913) (drained and gently squeezed), 7·7*grammes Decrease in weight, 3·4 grammes.
	0·58	0·59	0·61	0·44	0·46	0·49	0·50	Initial volume of nitrate solution, 4,000 c.c.
"Blank" Experiment.			October 14th.	October 28th.	November 14th.	December 23rd.	1913. January 28th.	Final volume of nitrate solution.†
Ammonium chloride solution.								
Ammoniacal nitrogen - -	—	—	0·49	0·41	0·41	0·42	0·41	
Nitrous ,, - -	—	—	—	0·0	0·0	0·0	0·0	
Nitric ,, - -	—	—	0·14	0·23	0·18	0·30	0·28	
	—	—	0·63	0·64	0·59	0·72	0·69	

* There was a small additional growth in the reservoir, which was not taken into account.

† The solutions are still in use at time of writing.

ADDENDUM II. TO SECTION I.

Does Nitrification take place in Streams Receiving Sewage Liquors and Effluents?

As an attempt to answer this question, a study has been made of the comparative pairs of river water samples, whose analyses are partly given in Tables I. and II., pp. 64A and 64B, with the following results:—

TABLE III.

Synopsis of Comparative Samples of River Water in Tables I. and II., pp. 64A and 64B.

	Average reduction.*	Number of pairs of samples.	Average increase.*	Number of pairs of samples.
(1) *All Samples of River Water receiving Land or Filter Effluent.*				
Chlorine	29%	19	17%	12
Nitric (plus nitrous) nitrogen	12%	12	39%	16
(2) *Samples drawn in the Seven Warm Months* † *(these are included in* (1)).				
Chlorine	22%	11	7%	8
Nitric (plus nitrous) nitrogen	13%	9	46%	13
(3) *All Samples of River Water receiving Sewage or Tank Liquor.*				
Chlorine	8%	10	1%	7
Nitric (plus nitrous) nitrogen	28%	11	24%	7
(4) *Samples drawn in the Seven Warm Months (these are included in* (3)).				
Chlorine	8%	8	1%	6
Nitric (plus nitrous) nitrogen	30%	10	21%	6

Whether we consider, in Tables I., II., and III., all the pairs of samples of river water receiving *effluent*, or only those pairs drawn during the warmer months of the year, we find:—

(*a*) That more samples show a reduction in chlorine than in nitric nitrogen.

(*b*) That the average percentage reduction in chlorine is greater than the average percentage reduction in nitric nitrogen.

(*c*) That more samples show an increase in nitric nitrogen than in chlorine.

(*d*) That the average percentage increase is much greater in the case of the nitric nitrogen.

In the case of those pairs of samples of river water receiving *sewage or tank liquor*, we find:—

(*e*) That slightly fewer samples show a reduction in chlorine than in nitric nitrogen.

(*f*) That the average percentage reduction in chlorine is less than the average percentage reduction in nitric nitrogen.

(*g*) That equal numbers of samples show an increase in nitric nitrogen and chlorine (but the increase in chlorine is so small as to be negligible).

(*h*) That the average percentage increase is much greater in the case of the nitric nitrogen.

To attempt to draw conclusive deductions from the foregoing results is extremely difficult, when we reflect that the following factors, among others, come into play:

(1) In the river water samples which have been compared, admixture of effluent (or of sewage liquor) and river water was supposed to have been complete in the lower sample. Judging by the internal evidence yielded by some of the chlorine figures, however, this cannot always have been the case.

(2) All streams receive greater or less accessions of ground water (the stream at Buxton furnishes an extreme case of this). Ground water usually contains much less chlorine and usually much less nitrate than a sewage effluent (but more nitrate than a sewage liquor), hence the amounts of chlorine and of nitrate found in the lower of the two river samples must (in the case of effluents at all events) be less than if no ground water had entered.

(3) Both chlorine and nitrate are taken up by algæ and aquatic plants; this will tend to reduce further both of these constituents in the lower sample.

(4) The ammonia added by an effluent to river water is evidently largely taken up directly by the vegetation, without first being converted into nitrate.

(5) The percentage figures for reduction or increase of chlorine and of nitrate are based on very different actual amounts of these constituents.

(6) It is probably quite safe to assume that the chlorine in a polluted water is not taken up by algæ and aquatic plants in greater proportion to the total amount present than the nitric nitrogen (if analogy with nutrition of land plants holds good here, it will be taken up in less proportion).

Allowing for all the considerations which have just been brought forward, the foregoing analysis of Table III., excepting paragraph (*f*), goes to indicate that nitrification does take place in the water of a polluted stream, as it flows along.

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* A few pairs of samples showed neither reduction nor increase in one or the other constituent.

† April, May, June, July, August, September and October.

NOTE.—Though not perhaps exactly germane to the point which has just been under discussion, it may be of interest to refer here to Tables I. and II. in Section 6, pp. 134–135 of this Appendix, and to diagram C., facing p. 66 in this section. It will be seen that in the first four divisions of the samples (according to the state of the river) there is in both tables a progressive average increase in the figure for nitric nitrogen, and that in Table II. this increase continues until the state of the river becomes bad. The few figures bearing on this point may be again given here :—

ALL SAMPLES OF RIVER WATER DRAWN :—

State of River.	*Above* sewage or effluent outfall.		*Below* sewage or effluent outfall.	
Parts per 100,000	Nitric nitrogen.	Number of samples.	Nitric nitrogen.	Number of samples.
Very clean - - - - - -	0·066	12	0·040	7
Clean - - - - - - -	0·186	72	0·205	87
Fairly clean - - - - - -	0·208	39	0·231	45
Moderately clean - - - - -	0·256	14	0·263	71
Doubtful - - - - - - -	—	—	0·493	89
Bad - - - - - - - -	—	—	0·395	47

ADDENDUM III.

TABLE IV.—GIVING DETAILS OF THE SAMPLES IN DIAGRAM A, p. 65A.

SAMPLES DRAWN ABOVE OUTFALL.

Date.	Number in diagram.	Number of sample.	Place.	Dissolved oxygen taken up in 5 days.	"Oxygen absorbed" in 4 hours.	Ammoniacal nitrogen.
June 16th, 1910	1	176 K	Pickering	0·03	·078	·003
May 31st, 1911	2	329	Malton	0·05	·124	·008
May 26th, 1910	3	164 K	Wilpshire	0·06	·171	·005
Oct. 4th, ,,	4	291	St. Neots	0·07	·155	·009
Oct. 4th, ,,	5	288	Huntingdon	0·07	·178	·008
Oct. 5th, ,,	6	G 6	Hartley Wintney	0·08	·205	·004
May 23rd, 1911	7	320	Rugby	0·09	·310	·038
July 12th, 1910	8	222	Hartley Wintney	0·10	·355	·007
Oct. 6th, ,,	9	6 C	Alderley Edge	0·11	·517	·020
July 13th, ,,	10	227	Wye	0·11	·276	·007
July 28th, ,,	11	A	Huntingdon	0·12	·201	·009
Oct. 6th, ,,	12	1	Lincoln	0·12	·369	·162
Oct. 6th, ,,	13	299	Pickering	0·12	·191	·003
July 5th, ,,	14	188 K	Rugby	0·12	·263	·028
Feb. 17th, 1911	15	266 K	Berkhamsted	0·14	·172	·007
Aug. 11th, 1910	16	235	Chelmsford	0·14	·263	·020
Oct. 4th, ,,	17	1 C	Chelmsford	0·14	·272	·013
Feb. 8th, 1911	18	257 K	Malton	0·14	·226	·007
Oct. 14th, 1909	19	1	Buxton	0·15	·245	·006
Aug. 12th, 1910	20	239	Cambridge	0·15	·126	·009
July 4th, 1911	21	2017	Chelmsford	0·16	·255	·010
June 14th, 1910	22	173 K	Malton	0·16	·168	·009
June 7th, 1911	23	336	Berkhamsted	0·17	·117	·014
May 24th, 1910	24	161 K	Hartley Wintney	0·18	·290	·011
June 8th, ,,	25	217	St. Neots	0·18	·288	·007
Sept. 21st, ,,	26	263	Tiverton	0·18	·114	·002
Oct. 29th, 1909	27	20 C	Wilpshire	0·18	·190	·016
Oct. 4th, 1910	28	G 1	Wye	0·18	·255	·192
Feb. 16th, 1911	29	263 K	Wye	0·18	·139	·051
June 22nd, 1910	30	182 K	Berkhamsted	0·19	·216	·027
May 24th, 1911	31	326	Buxton	0·19	·063	·005
June 23rd, 1910	32	185 K	Cambridge	0·20	·232	·012
Dec. 1st, 1909	33	113 K	Huntingdon	0·20	·259	·022
June 16th, 1911	34	1023 C	Chelmsford	0·21	·210	·014
Feb. 23rd, ,,	35	272 K	Kenilworth	0·22	·358	·016
Dec. 14th, 1909	36	116 K	St. Neots	0·22	·381	·010
June 21st, 1910	37	179 K	Chelmsford	0·24	·291	·003
June 14th, ,,	38	A	Lincoln	0·24	·365	·008
Feb. 10th, 1911	39	260 K	Buxton	0·24	·077	·018
Aug. 17th, 1910	40	243	Kenilworth	0·25	·406	·050
Jan. 23rd, 1911	41	132 K	Rugby	0·25	·224	·019
May 15th, ,,	42	1005 C	Rugby	0·25	·276	·009
June 6th, ,,	43	300 K	Rugby	0·25	·369	·013
Jan. 16th, ,,	44	129 K	Chelmsford	0·26	·297	·022
June 8th, 1910	45	170 K	Higham Ferrers	0·27	·310	·038
Sept. 29th, ,,	46	278	Kenilworth	0·29	·498	·047
Feb. 24th, 1911	47	275 K	Stratford	0·29	·316	·059
May 3rd, 1910	48	150 K	Kenilworth	0·31	·268	·010
May 9th, 1911	49	1	Lincoln	0·32	·271	·029
June 20th, ,,	50	303	Rugby	0·34	·300	·080
Jan. 24th, ,,	51	248 K	Nuneaton	0·37	·348	·182
May 30th, ,,	52	1016 C	Alderley Edge	0·38	·399	·018
June 1st, 1910	53	167 K	Wye	0·38	·297	·090
June 19th, 1911	54	2011	Wye	0·38	·274	·016
May 23rd, ,,	55	323	Coventry	0·39	·322	·007
April 27th, 1910	56	209	Nuneaton	0·39	·412	·206
July 18th, 1911	57	1	Lincoln	0·39	·469	·168
May 4th, ,,	58	2000 G	Buxton	0·40	·283	·032
May 9th, ,,	59	2005	Wye	0·43	·280	·102
July 6th, ,,	60	242	Buxton	0·44	·197	·294
May 3rd, ,,	61	1000 C	Chelmsford	0·47	·268	·003
July 10th, ,,	62	352	Wye	0·49	·341	·056
May 4th, 1910	63	154 K	Stratford	0·50	·403	·003
Nov. 16th, 1909	64	110 K	Ollerton	0·61	·314	·175
May 22nd, 1911	65	1	Lincoln	0·65	·400	·017

TABLE V.—GIVING DETAILS OF THE SAMPLES IN DIAGRAM B, p. 65A.

SAMPLES DRAWN BELOW OUTFALL.

Date.	Number in diagram.	Number of sample.	Place.	Dissolved oxygen taken up in 5 days.	"Oxygen absorbed" in 4 hours.	Ammoniacal nitrogen.
Oct. 5th, 1910	1	G 8	Hartley Wintney	0·06	·219	·035
June 16th, ,,	2	178 K	Pickering	0·06	·138	·012
Oct. 4th, ,,	3	292	St. Neots	0·06	·164	·007
Sept. 4th, 1908	4	19	Stratford Bridge	0·07	·240	·024
Nov. 16th, 1909	5	112 K	Ollerton	0·08	·260	·160
July 28th, 1910	6	D	Huntingdon	0·09	·205	·017
Oct. 6th, ,,	7	302	Pickering	0·09	·266	·041
Oct. 4th, ,,	8	289	Huntingdon	0·10	·189	·010
Sept. 28th, ,,	9	269	Rugby	0·12	·307	·021
Oct. 29th, 1909	10	22 C	Wilpshire	0·12	·190	·058
Aug. 25th, 1909	11	124	Warwick	0·13	·354	·025
July 4th, 1911	12	2021	Chelmsford	0·14	·386	·023
July 12th, 1910	13	224	Hartley Wintney	0·14	·338	·025
Jan. 23rd, 1911	14	138 K	Rugby	0·14	·210	·025
July 13th, 1910	15	230	Wye	0·14	·258	·014
Oct. 14th, 1909	16	4	Buxton	0·15	·161	·006
June 12th, 1911	17	339	Berkhamsted	0·16	·224	·172
June 12th, ,,	18	340	Berkhamsted	0·17	·186	·106
Feb. 10th, ,,	19	262 K	Buxton	0·17	·037	·014
Aug. 17th, 1910	20	246	Kenilworth	0·17	·307	·012
Feb. 8th, 1911	21	259 K	Malton	0·17	·189	·014
May 31st, ,,	22	334	Malton	0·18	·182	·043
Dec. 14th, 1909	23	118 K	St. Neots	0·18	·394	·011
Sept. 4th, 1908	24	18	Barford Mill	0·18	·300	·088
Oct. 4th, 1910	25	G 5	Wye	0·18	·198	·028
June 12th, 1911	26	341	Berkhamsted	0·19	·190	·079
May 23rd, 1911	27	322	Rugby	0·19	·329	·011
May 26th, 1910	28	166 K	Wilpshire	0·19	·284	·216
Aug. 25th, 1909	29	123	Warwick	0·20	·474	·268
Oct. 4th, 1910	30	5 C	Chelmsford	0·22	·261	·116
Feb. 17th, 1911	31	268 K	Berkhamsted	0·23	·158	·077
Feb. 24th, ,,	32	277 K	Stratford	0·23	·319	·055
May 9th, 1911	33	2009	Wye	0·24	·225	·085
July 5th, 1910	34	190 K	Rugby	0·25	·300	·059
June 19th, 1911	35	2016	Wye	0·25	·256	·006
Aug. 12th, 1910	36	241	Cambridge	0·27	·164	·045
May 24th, 1911	37	328	Buxton	0·28	·095	·027
Sept. 29th, 1910	38	277	Kenilworth	0·29	·297	·013
Jan. 23rd, 1911	39	140 K	Rugby	0·29	·239	·042
Jan. 23rd, ,,	40	141 K	Rugby	0·30	·243	·077
Sept. 21st, 1910	41	265	Tiverton	0·30	·160	·010
Aug. 11th, ,,	42	238	Chelmsford	0·30	·302	·099
June 23rd, ,,	43	187 K	Cambridge	0·31	·242	·025
May 24th, ,,	44	163 K	Hartley Wintney	0·31	·329	·026
July 6th, 1911	45	245	Buxton	0·32	·092	·016
Dec. 1st, 1909	46	115 K	Huntingdon	0·32	·278	·028
June 20th, 1911	47	305	Rugby	0·32	·357	·029
June 16th, ,,	48	1026 C	Chelmsford	0·36	·331	·066
June 8th, 1910	49	172 K	Higham Ferrers	0·36	·320	·033
May 4th, 1911	50	2002 G	Buxton	0·37	·095	·027
May 3rd, 1910	51	153 K	Kenilworth	0·38	·325	·014
Oct. 6th, ,,	52	10 C	Alderley Edge	0·39	·527	·096
May 4th, ,,	53	156 K	Stratford	0·39	·290	·008
Feb. 16th, 1911	54	265 K	Wye	0·39	·194	·058
June 14th, 1910	55	175 K	Malton	0·41	·212	·008
June 1st, ,,	56	169 K	Wye	0·42	·284	·076
June 21st, 1911	57	181 K	Chelmsford	0·42	·363	·083
June 8th, 1910	58	221	St. Neots	0·44	·326	·003
Jan. 22nd, ,,	59	184 K	Berkhamsted	0·45	·192	·036
Oct. 6th, ,,	60	6	Lincoln	0·45	·581	·849
May 23rd, 1911	61	325	Coventry	0·50	·380	·047
May 15th, ,,	62	1010 C	Rugby	0·50	·326	·052
Feb. 23rd, ,,	63	274 K	Kenilworth	0·50	·466	·063
May 3rd, ,,	64	1004 C	Chelmsford	0·51	·346	·107
April 27th, 1910	65	212	Nuneaton	0·54	·553	·326
Jan. 16th, 1911	66	131 K	Chelmsford	0·55	·396	·172
May 9th, ,,	67	4	Lincoln	0·62	·474	·054
Jan. 24th, ,,	68	250 K	Nuneaton	0·68	·546	·376
May 30th, ,,	69	1020 C	Alderley Edge	0·77	·487	·162
May 22nd, ,,	70	2	Lincoln	0·86	·371	·162
June 14th, 1910	71	D	Lincoln	0·59*	·586	·160
June 2nd, 1911	72	302 K	Rugby	0·57*	·637	·199

* Oxygen exhausted.

SECTION 2.

(Sections 2, 3 and 9 should be read in conjunction.)

DETERMINATION OF DISSOLVED OXYGEN ABSORPTION IN 5 DAYS.

For the carrying out of this test we have used the method of Winkler,[*] as modified by Rideal and Stewart.[†] As will be seen, however, from what follows, much work has been done in the course of the investigation with the object of arriving at the limitations of the test, the error of experiment under given conditions, etc.

As illustrating the accuracy of this volumetric method, we may quote some comparative figures showing the results obtained by (*a*) the gasometric method (*i.e.*, by boiling the gases out of the sample and analysing them); and (*b*) the Winkler method. These determinations were made by Professor Letts and Mr. E. H. Richards on mixtures of 1 per cent. Belfast sewage with (*a*) tapwater; and (*b*) sea-water.[‡] The mixtures were saturated with air at 60°, 70° and 80° F. and incubated in full stoppered bottles at those temperatures. The gasometric determinations were made by one observer and the volumetric by the other. As will be seen from the table of figures below, the concordance between the two sets of results is excellent throughout.

The figures give the dissolved oxygen expressed as c.c. per litre at N.T.P.

	When Mixed.			After 5 Days at			After 14 Days at			After 42 Days at		
				60° F.	70°	80°	60° F.	70°	80°	60° F.	70°	80°
Tap-water mixture :												
Oxygen (gasometric) - - -	6·2	6·0	5·4	5·0	4·1	3·0	4·2	4·2	0·9	2·9	7·1*	0·2
Oxygen (Winkler) - - -	6·6	5·9	5·5	5·0	4·0	3·0	4·0	4·2	0·9	2·9	7·4	0·1
Sea-water mixture :												
Oxygen (gasometric) - - -	5·5	5·1†	4·7	3·9	3·5	2·7	3·3	3·2	1·6	2·7	2·5	0·2
Oxygen (Winkler) - - -	5·7	5·4	5·0	4·0	3·6	2·8	3·2	3·1	1·5	2·5	2·3	0·1

* Green algæ developed in this bottle.

† Calculated mean of results at 60° and 80° F.

For the determination of the dissolved oxygen taken up by effluents in 5 days, we recommend that, for purposes of a standard, the dilution should be 1 volume effluent plus 4 volumes good tap-water. Further, if the test is to be made for purposes of a standard, we would suggest that it be done in duplicate, and that the mean of the two results be taken as the final result. If, as might conceivably happen on a rare occasion, the two results should differ widely, a fresh duplicate determination should be made from a new sample.

In theory, it would be desirable, for purposes of comparison, if the dilutions for different effluents could always be so arranged that the same proportion of oxygen (say, 50 per cent. of the whole) were used up during the 5 days' incubation. In practice, however, assuming 4 volumes of water to be always taken for dilution, this would be impossible, for it is obvious that less oxygen will be taken up by a high-class effluent than by one of moderate quality only.

For purposes of a standard test, therefore, the dilution must be primarily arranged to meet the requirements of an effluent which approaches the limit of the proposed standard (in this case, 2 parts dissolved oxygen absorption in 5 days).

We have found by experience that, in order to make the percentage difference between duplicate estimations as small as possible, *i.e.*, to obtain the most accurate determinations of dissolved oxygen absorption in any period up to 5 to 7 days, the dilution of the sample should be such that about 50 to 60 per cent. of the available oxygen is taken up.

A mixture of 4 volumes of water plus 1 volume of effluent will contain oxygen equivalent to about 4·0 to 4·5 parts per 100,000 of effluent, so that in the case of an effluent whose figure for dissolved oxygen absorption in 5 days does not exceed 2·0, something under 50 per cent. of the available oxygen will be required.

If less than 30 per cent. of the available oxygen is taken up, the error of experiment may become more appreciable, but in such case the effluent will be shown to be so much better than the standard that this will be of no consequence.

If the dilution with tap-water is very great, relatively to the amount of pabulum and the number of bacteria originally present, the absorption of oxygen may be somewhat retarded, *i.e.*, the rate of absorption in 5 days may be somewhat less than with a small dilution. But up to a dilution of 4 volumes it may be taken that this is not the case (unless with an exceptionally pure effluent).

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[*] *Berichte*, Vol. XXI., p. 2,843 (1888).

[†] *Analyst*, Vol. XXVI., p. 141 (1901).

[‡] Seventh Report of the Commission, Vol. II., Appendix III., p. 111.

The following examples (up to 1 plus 4 dilution) illustrate the latter point (the other figures of analysis cited are merely intended as an additional index to the quality of the samples):—

	Parts per 100,000.		
	A. Percolation Effluent.	B. Mixture of Percolation and Contact Effluents.	C. Percolation Effluent with the Solids settled out.
Drawn	Nov. 14th, 1910.	Dec. 2nd, 1910.	Sept. 27th. 1911.
Analysed	Nov. 16th, 1910.	Dec. 5th, 1910.	Oct. 3rd, 1911.
Ammoniacal nitrogen	1·40	0·67	1·68
Albuminoid nitrogen	0·08	0·11	0·17
Nitrous nitrogen	0·08	0·07	—
Nitric nitrogen	1·22	1·69	—
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C.	0·60	0·87	—
Solids in suspension	None.	Very little.	—
Dissolved oxygen taken up in 5 days at 18° C.:—			
No dilution	0·55	—	—
Dilution with 1 vol. tap-water	0·55	0·50	0·72
„ „ 2 vols. „	0·48	0·62	0·67
„ „ 4 vols. „	0·50	0·59	0·74

This test involves the use of an incubator maintaining a temperature of 18·3° C. (65° F.).

The reason for selecting the above temperature for the test is that it is unusual in this country, so far as our observations go, for even a sluggish river water (in a non-manufacturing district) to exceed it. During the investigations made for the Commission on the purification of sewage by land, daily records of effluent temperatures were taken at various farms for a year* and, more recently, the daily temperatures of various rivers and streams were taken over a similar period (*see* Diagram F, p. 94A). These two sets of records, taken conjointly, support the above conclusion. Temperature records of the rivers Thames and Lee, for the year ending March, 1911, also show 65° F. to be somewhere near the maximum summer temperatures of those rivers. The mean monthly temperature of the river Cherwell, during the month when its temperature was highest, for two separate periods of ten years (1882–91) and twelve years (1892–1903), was found to be 64·6° and 65·7° F.†; these readings were taken at 10 a.m.

The temperature of the incubator should not vary more than 1° on either side of the standard temperature (18·3° C.) The following examples show that the figure obtained for dissolved oxygen absorption by an effluent is materially greater when the temperature of the incubator is 4° to 6° higher than that. The dilution given to the effluent was in each case 4 volumes of tap water. In experiment (*a*) the incubators were read twice a day; in (*b*) and (*c*) the temperatures were not checked quite so carefully, but they may be taken as being substantially correct:—

Date of Experiment.	Nature of Sample.	Dissolved Oxygen taken up by 100,000 parts of Effluent.	
		at 18° C.	at 23°–24° C.
(*a*) February 20th, 1912	Percolation Effluent	0·78	1·13
(*b*) February 9th, 1912	Percolation Effluent	3·03	3·97 + x * (22° C.)
(*c*) February 9th, 1912	Percolation Effluent	2·65	3·89

* " + x " means that the oxygen was exhausted.

It is essential that the tap water with which the determinations are made should be at or close to 18° C. This is conveniently managed by filling a Winchester quart bottle about two thirds full with water and keeping it at that temperature over-night. The bottle must be well shaken up some little time before the determinations are made (not immediately before, as in that case the small air-bubbles would not have time to escape); this ensures the water not being super-saturated at that temperature.

Unless these precautions are taken, the diluting water, if cold, will almost certainly contain more dissolved oxygen than corresponds to saturation at 18° C., and if it be mixed with a well-oxygenated effluent and the mixture be incubated for 5 days at 18° C., there may be some loss of oxygen. This is seen from the following examples of mixtures which were made at temperatures varying from 5° to 18° C., and which were then incubated at the latter temperature as usual. As will be seen, most of these estimations were made in duplicate:—

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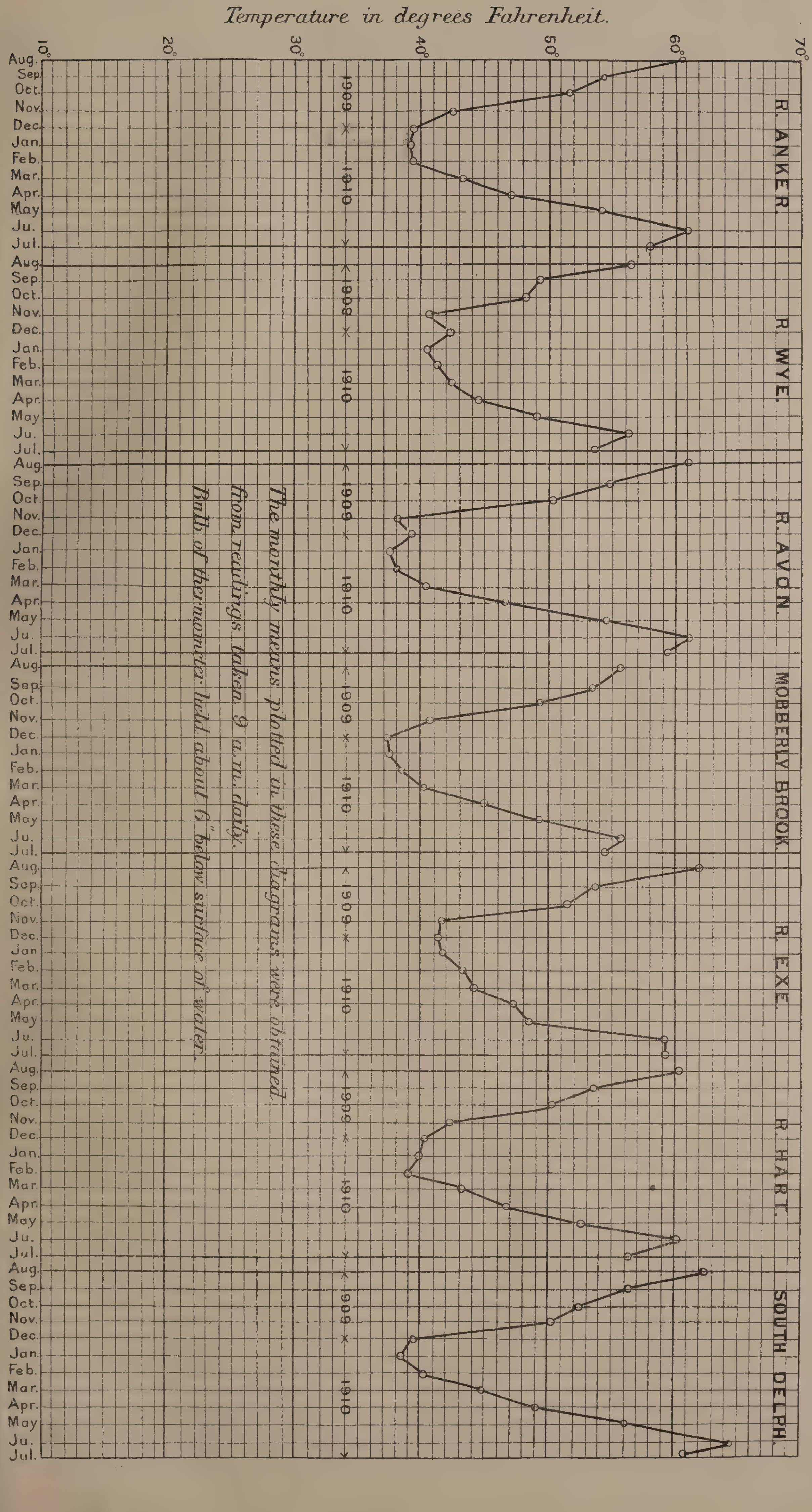
* Fourth Report, Vol. IV., Part I., p. 40.

† A History of the Daubeny College Laboratory, Magdalen College, Oxford (published by Henry Frowde, 1904).

DIAGRAM F

MEAN MONTHLY TEMPERATURES OF SOME RIVER WATERS.



The monthly means plotted in these diagrams were obtained from readings taken 9 a.m. daily.
Bulb of thermometer held about 6" below surface of water.

to face page 94.

Date of Experiment.	Nature of Sample.	Dilution (Vols. Tap-water).	Temperature of liquid when placed in Incubator.	Number of Days Incubated.	Parts per 100,000 by Weight.				
		Eff. T.W.			Oxygen at Start.	Oxygen at End.	Oxygen used up.	Difference between the two Estimations.	Oxygen taken up by Sample.
January 23rd, 1912.	Good percolation effluent from brewery waste septic tank liquor.	1 plus 2	7° C.	6	1·018	0·509	0·509	—	1·53
	” ”	1 ” 2	18° C.	6	0·955	0·532	0·423	0·086	1·27
February 5th, 1912.	Ealing percolation effluent (containing, say, 5 to 6 parts suspended solids).	1 ” 4	5° C.	5	1·096 1·110	0·574* 0·580*	0·526	—	2·63
	” ”	1 ” 4	18° C.	5	0·860 0·880	0·407* 0·404*	0·464	0·061	2·33
February 8th, 1912.	Accrington percolation effluent (abnormal, being drawn when the filter was thickly coated with ice. Rather turbid, with a little suspended solid).	1 ” 4	7° C.	5	1·008 1·022	0·230 0·230	0·785	—	3·93
	” ”	1 ” 4	18° C.	5	0·750 0·755	0·072 0·070	0·682	0·103	3·41
February 8th, 1912.	Rugby effluent from High Level (very little suspended solids).	1 ” 4	7° C.	5	1·017 1·020	0·762 0·750	0·263	—	1·32
	” ”	1 ” 4	18° C.	5	0·840 0·830	0·632 0·635	0·198	0·065	0·99
January 31st, 1912.	Hendon precipitation liquor - - - - - - -	1 ” 24	6° C.	5	1·122 1·130	0·950 0·961	0·171	—	4·25
	” ” - - - - - - -	1 ” 24	12° C.	5	1·052 1·032	0·893 0·879	0·156	0·015	3·90
	” ” - - - - - - -	1 ” 24	18° C.	5	0·870 0·841	0·743 0·748	0·110	0·046	2·75

* These pairs of figures are the mean of three determinations, the middle one being used twice.

In all of the above cases a higher *apparent* figure was obtained for dissolved oxygen absorption when the mixture was put into the incubator cold, *i.e.*, when at the start it contained more oxygen than corresponded to saturation at 18° C.

It might perhaps be contended that the question of concentration of the dissolved oxygen in the mixture relative to the amount of oxygen used up came in here, but the experiments quoted in Addendum A, p. 100, show that it does not, at least not to any practical extent.

It may be added here that a good tap-water (or any water containing very little oxidisable matter) may show little or no loss of oxygen though put in the incubator at a low temperature, and then incubated for 5 days at 18° C. It appears to remain super-saturated, thus :—

A sample in duplicate of Ealing tap water at 7° C. (23rd January, 1912) was placed in the 18° C. incubator for 6 days, the oxygen being determined at the start and finish as usual :—

	(a)	(b)	Mean.
The oxygen at the start was	1·132	1·150	1·140
,, ,, end ,,	1·123	1·120	1·122

The normal dissolved oxygen content at 18·3° C. is 0·928. (Roscoe and Lunt.)*

The reason for this no doubt is that, with such a very small amount of organic impurity present, the gas produced by the fermentative change in 5 days is so small as to be negligible, and hence the condition of super-saturation is not likely to be disturbed.

When, however, during the fermentation of a mixture of effluent and water, a bubble of nitrogen gas lodges at the top of the bottle, that bubble will act as a vacuum to the oxygen in solution in the water, and consequently a little oxygen will also find its way into the bubble, the amount varying with the amount of oxygen dissolved in the liquid.

For this reason there is no doubt in most cases a very slight loss of gaseous oxygen in the 5 days' test, but that this loss is not serious (is negligible, in fact) is readily proved by measuring the volume of the bubble, only a small fraction of which can consist of oxygen.

On the other hand, as is well-known, when the fermentation of a mixture of sewage and water or effluent and water is carried to its full extent, *i.e.*, over a comparatively long period of time, the quantity of oxygen in the evolved gases, relatively to the quantity remaining in the liquid, is material, and it has to be taken into account. A few examples of this may be adduced here, the figures given in the last three columns representing c.c. per litre at N.T.P. :—

Place where Sample was taken.	Date.	Nature of Sample.	Number of Sample.	Total Gas at top of Jointed Bottle.	Oxygen in gas at top of Jointed Bottle.	Oxygen remaining in Liquid.
Dorking -	Oct., 1908	Limed septic liquor filtered through Gooch crucible.	—	2·520	0·408	3·570
Coleburn -	Oct., 1908	Limed pot ale - - - -	—	1·473	0·206	2·870
Rochdale	June, 1907	Percolation effluent - - -	3,688	2·461	0·302	2·507
Accrington -	June, 1907	Contact effluent - - - -	465	2·038	0·097	0·420
Accrington -	July, 1907	Percolation effluent - - -	615	2·636	0·396	3·512
Caterham -	July, 1907	Percolation effluent - - -	17	1·932	0·174	1·876

A few control determinations with tap-water alone should be done from time to time, to make sure that the tap-water itself does not take up any appreciable quantity of oxygen.

The following figures were obtained with Ealing tap-water (omitting an abnormal result on September 29th) :—

	Parts per 100,000 by Weight.	
	Oxygen at Start.	Oxygen at End.
June 13th, 1911 - -	0·505	(*a*) 0·505 (*b*) 0·515
June 28th, 1911 - -	(*a*) 0·758 (*b*) 0·752	0·755 0·750
September 28th, 1911 -	(*a*) 0·676 (*b*) 0·697	0·662 0·678
October 3rd, 1911 - -	(*a*) 0·880 (*b*) 0·850	0·880 0·865

The solutions required for the determination are :—

(1) Concentrated sulphuric acid.

(2) $\frac{N}{8}$ Permanganate (3·94 grm. $KMnO_4$ per litre).

(3) Potassium oxalate (2 per cent. of the crystallised salt, $K_2C_2O_4 + H_2O$).

(4) Manganous chloride (33 per cent. of the crystallised salt, $MnCl_2 + 4H_2O$).

(5) A mixed solution of caustic potash and iodide of potassium containing 70 grms. KOH and 10 grms. KI per 100 c.c.

(6) Concentrated hydrochloric acid (free from chlorine).

(7) About $\frac{N}{20}$ sodium thiosulphate solution (*i.e.*, containing about 12 grms. of the salt per litre).

Well-fitting stoppered bottles of 340 to 360 c.c. are used for the test, each bottle being calibrated and the volume marked on it. If any difficulty arises with small bubbles of air, when a bottle is being closed, the lower part of the stopper may be slightly rounded by grinding, previous to use.

These bottles must, of course, be scrupulously clean, and in cold weather they must be warmed to about 18° C. before use.

The following experiment shows the extent to which water at about 18° C. may be reduced in temperature by being poured into very cold bottles :—

	I.	II.	III.
Volume of bottle - -	353 c.c.	349 c.c	353 c.c.
Temperature of bottle -	5·6° C.	5·3° C.	5·4° C.
Temperature of water added - - -	17·6° C.	17·6° C.	17·6° C.
Temperature of the water after standing in the stoppered bottle for about 10 minutes -	15°	15°	15°

If the temperature of the effluent sample is below 18° C.; it is to be brought to a temperature of about 18° C., just before the determination is made.

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* *Journ. Chem. Soc.*, Vol. LV., p. 569 (1889).

Method of Carrying out the Estimation.

The sample of effluent having been thoroughly mixed (as regards its liquid and solid portions) in the half-Winchester quart bottle in which it was taken, two portions of 200 c.c. each[*] are poured into measuring flasks for the determination of suspended solids (*see* p. 103). The remainder of the effluent in the sample bottle is then well shaken for half a minute or so[†], in order to bring its dissolved oxygen content to something near that of the diluting water. That this re-oxygenation can be readily brought about is shown by the following experiments :—

> (*a*) February 13th, 1912. 25 c.c. of a brewery waste septic tank liquor were added to a half-Winchester quart bottle full of tap-water, and the mixture was kept for three days at a temperature of about 18° to 20° C. The oxygen in solution in the water was now found to be 0·160 part per 100,000. The water remaining in the half-Winchester (about two-thirds of the whole) was then shaken vigorously for one minute, when it was found to contain 0·782 part of oxygen.
>
> (*b*) February 20th, 1912. A similar mixture to the above now contained 0·020 oxygen. After being shaken for half a minute, 0·775 oxygen.
>
> (*c*) February 21st, 1912. A similar mixture contained 0·035 oxygen. After being shaken for 15 seconds, 0·840 oxygen.

The temperature of the liquid in this last bottle was 17° C. at the time of the estimation. Water fully saturated at that temperature contains 0·956 part of oxygen (Roscoe and Lunt, *loc. cit.*).

After a dilution has been made in a flask of ample size, and the contents of the flask have been gently but thoroughly mixed, the four bottles required for the duplicate determination are filled quietly and quickly, and so far as possible in a similar manner, with the diluted effluent, a little of the mixture being allowed to overflow. The bottles are left unstoppered for 5 minutes. If, during this time any tiny bubbles of air lodge in the shoulder, the bottle is gently tilted to displace them and allow them to escape. The bottles are then stoppered, being completely full of liquid. One bottle (B) is placed in the incubator for 5 days, while in the other (A) the oxygen in solution is at once determined, as follows :—

> 0·9 c.c. sulphuric acid is added, and then sufficient of the permanganate solution to leave a slight excess of the latter after the whole has been mixed and has stood for 20 minutes (stoppered, of course) ; 1 to 2 c.c. of the permanganate are nearly always sufficient for this.
>
> *After 20 minutes have elapsed,*[‡] the excess of permanganate is destroyed by the addition of about 1 c.c. of the oxalate solution, the bottle being at once re-stoppered and its contents mixed.
>
> When the liquid has become colourless,[§] the stopper is again removed, and 1 c.c. of the manganese chloride solution is run in from a pipette at the bottom of the bottle, and, immediately afterwards, 4 c.c. of the mixed potash and iodide solution are added ; in this latter case, the point of the pipette need only be a little below the surface of the liquid.[‡‡]
>
> The stopper having been again inserted, the bottle is turned over once or twice, to mix the contents, and after a few minutes turned over again and allowed to stand for a further few minutes. The second rotation (after a short interval from the first) ensures good settlement of the hydroxides of manganese.
>
> Five c.c. of the hydrochloric acid are now run in from a pipette, and the bottle is re-stoppered and kept in the shade for 5 to 10 minutes, with occasional rotation. Twenty c.c. of the liquid are now pipetted out of the bottle and rejected, and the remainder is titrated with thiosulphate, using some *clear* starch solution towards the end of the titration.

For practical purposes, no correction need be made for the 8 c.c. or so of added reagents (the hydrochloric acid hardly counts here). Assuming the sulphuric acid and the very concentrated solutions of manganous chloride and mixed iodide and potash to contain practically no oxygen in solution, there only remain about 3 to 4 c.c. (of oxalate and permanganate) to be considered.

If we assume these 4 c.c. as being saturated with oxygen, this means that the 8 c.c. added are half-saturated. The small error caused by the addition of the 8 c.c. to a bottle of—say—350 c.c. capacity—may operate in one of two directions. Taking the extremes :—

> (*a*) Supposing that the water which is being tested is fully saturated with oxygen, the 8 c.c. of reagents will reduce that oxygen by $\frac{4}{350}$ of saturation amount.
>
> (*b*) Supposing the water to have its oxygen exhausted, the 8 c.c. of reagents will add oxygen to the extent of $\frac{4}{350}$ of the saturation amount.
>
> (*c*) Supposing the sample to have its oxygen half exhausted, the addition of the reagents will have no effect one way or the other.

The maximum error from this cause in an oxygen estimation can therefore be only ± 1 per cent., and the maximum error in an estimation of dissolved oxygen absorption — 2 per cent. This is borne out by the fact that, when the oxygen in an incubated mixture is completely exhausted, then, after the addition of the various reagents specified above, usually only two drops of thiosulphate solution are required to discharge the blue colour produced on adding starch. This, on 330 c.c. of water, is equivalent to about 0·01 part oxygen per 100,000, *i.e.*, to 1 per cent. of saturation amount.

At the end of 5 days the oxygen remaining in solution in bottle (B) is determined in the same way. The difference between the two determinations represents the oxygen taken up by the effluent in the interval.

The dissolved oxygen is calculated as follows :—

If N = number of c.c. of thiosulphate used,
S = strength of thiosulphate expressed in grms. of oxygen per c.c.
V = volume of the bottle in c.c.

Then, dissolved oxygen, in parts per 100,000

$$= \frac{100{,}000 \times NS}{V}$$

To give an (imaginary) instance :—

One volume of effluent is incubated with 4 volumes of tap-water.

Dissolved oxygen in mixture at start :—

Vol. of bottle 341 − 20 = 321 c.c.
Thiosulphate used = 6·95 c.c.
Strength of thiosulphate = 0·0003773 grm. oxygen per c.c.

Hence, dissolved oxygen

$$= \frac{0{\cdot}0003773 \times 6{\cdot}95 \times 100{,}000}{321}$$

$$= 0{\cdot}817\ (a)$$

Dissolved oxygen in mixture at end of incubation :—

Vol. of bottle 338—20 = 318 c.c.
Thiosulphate used = 4·11 c.c.
Similarly, dissolved oxygen = 0·488 (*b*).

Subtracting (*b*) from (*a*) we have :—

Dissolved oxygen taken up by 100,000 parts of the mixture = 0·329 grm.

As the mixture was only one-fifth effluent, it is necessary to multiply this figure by 5, in order to get the absorption by 100,000 parts of effluent, *i.e.*, 1·65 grms.

The following examples give a fair idea of the error of experiment in this test, as done in duplicate :—

---

[*] In the case of tank liquors of average strength, two portions of 50 c.c. each will be sufficient for the determination of the suspended solids, and in the case of sewages of average strength, two portions of 25 c.c. each.

[†] This is unnecessary in the case of sewages and tank liquors, since very little of either of these, relatively to the diluting water, is used in making a dilution.

[‡] This length of time is necessary (*see* Addendum B., p. 101).

[§] In the case of poor effluents and tank liquors, a brown precipitate may form, and this must be given time to disappear.

[‡‡] When a number of estimations are being made, much time is saved by using pipettes with their ends cut off for the manganese and the alkaline iodide solutions.

Date.	Place where Sample was taken.	Nature of Sample.	Dilution (Vols. Tap-water).	Number of Days Incubated	Parts per 100,000 by Weight.				
					Oxygen at Start (*a*).	Oxygen at End (*b*).	Oxygen used up (*a–b*).	Oxygen used up by Effluent (*a–b*) × 5.	Difference.
November 29th, 1910.	Ealing	Percolation effluent	Eff. T.W. 1 plus 4	6	0·929 0·926	0·675 0·690	0·254 0·236	1·27 1·18	0·09
December 5th 1910.	Hendon	Contact effluent	1 ,, 4	5	0·780 0·775	0·600 0·622	0·180 0·153	0·90 0·76	0·14
December 7th, 1910.	Hendon	Contact effluent	1 ,, 4	5	0·868 0·869	0·716 0·724	0·152 0·145	0·77 0·73	0·04
September 28th, 1911.	Ealing	Percolation effluent	1 ,, 4	4	0·820 0·832	0·700 0·695	0·120 0·137	0·60 0·69	0·09
January 5th, 1912.	Hartley Wintney	Land effluent	1 ,, 4	5	0·852 0·856	0·638 0·636	0·214 0·220	1·07 1·10	0·03
February 5th, 1912.	Ealing	Percolation effluent	1 ,, 4	5	0·860 0·880	0·407* 0·404*	0·453 0.476	2·27 2·38	0·11
February 8th, 1912.	Accrington	Percolation effluent (drawn during severe frost)	1 ,, 4	5	0·750 0·755	0·072 0·070	0·678 0·685	3·39 3·43	0·04
February 8th, 1912.	Rugby	Percolation effluent	1 ,, 4	5	0·840 0·830	0·632 0·635	0·208 0·195	1·04 0·98	0·06

* These two figures are the mean of three determinations, the middle one being used twice.

For the figures in Columns 8 and 9 of the foregoing table, no choice has been made when deducting the figure for oxygen at the start from that for oxygen at the end. In practically every case, however, the figures in Column 8 give the maximum disagreement; *e.g.*, taking the first example, instead of the figures $\genfrac{}{}{0pt}{}{0{\cdot}254}{0{\cdot}236}$ we might take $\genfrac{}{}{0pt}{}{0{\cdot}251.}{0{\cdot}239}$ The most probable result is got by taking the mean.

With careful working, at this dilution (1 + 4) the difference between duplicate estimations should thus not exceed about 0·1 part dissolved oxygen absorption per 100,000 parts of effluent. This represents an error of 5 per cent. in an effluent taking up 2 parts of oxygen.

As regards the estimation of dissolved oxygen in samples containing much suspended solid, *Cf.* Addendum, D., p. 102. (For further data, *see* Addendum, C., p. 101.)

If a *more stringent effluent standard* were fixed for any given place—say, a standard of 1 part dissolved oxygen absorption in 5 days, it would be advisable, for the reasons already given on p. 93, that the dilution should be :—

1 vol. of effluent plus 2 vols. tap-water.

Sewages and Tank Liquors.—For *tank liquors* the dilution for the 5 days test would usually be 49 volumes of tap-water, and for *sewages* 99 volumes. It is, however, impossible to lay down a hard and fast rule here, seeing that both sewages and tank liquors vary considerably in strength. For a weak tank liquor, 49 volumes of water would be too much, while a very strong sewage might require 199 volumes. Here, again, it is advisable not to use up in the 5 days more than about 50 per cent. of the oxygen present, while it is also advisable not to retard the action, or add to the multiplication error of experiment, by too great dilution.

If the nature of the sewage liquor to be tested is unknown, it is well to make a number of dilutions (each in duplicate), say, 1 + 9, 1 + 24, 1 + 49, and 1 + 99. The results obtained will show which of the dilutions was the most appropriate.

In Section 9, p. 172, specific recommendations are made as to the length of time which may reasonably be allowed to elapse between the drawing and analysis of samples for standard purposes.

ADDENDUM A. TO SECTION 2.

THE EFFECT OF CONCENTRATION OF DISSOLVED OXYGEN UPON ITS RATE OF ABSORPTION BY AN EFFLUENT.

In order to test this point, the following estimations were made by Mr. Girvan, Mr. Carter and Mr. Richards.

Two Winchester and three half-Winchester quart bottles were filled with percolation effluent at Hendon on June 28th, 1911, and were allowed to rest in the laboratory for a day following their arrival. On June 30th the greater part of the liquid in one of the Winchesters was siphoned from deposited solids into another Winchester, which was filled up with some more of the effluent, siphoned from one of the smaller bottles. This liquid gave the following figures on analysis:—

	Parts per 100,000
Ammoniacal nitrogen - - -	1·88
Albuminoid nitrogen - - -	0·13
Nitrous nitrogen - - - -	0·0
Nitric nitrogen - - - -	0·35
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.) - - - - -	1·12

600 c.c. of the above liquid (*a*) were now siphoned into a half Winchester full of air, while the 1900 c.c. left in the Winchester (*b*) were vigorously shaken so as to oxygenate that liquid thoroughly. 600 c.c. of (*b*) were then added to and mixed with the 600 c.c. of (*a*), and this mixture (which was expected to be about half-aerated) was in its turn siphoned into four smaller bottles of about 280 c.c. capacity each, which had been previously filled with carbon dioxide. The remainder of (*b*) was then used to fill four similar small (CO_2-containing) bottles.

There were thus eight small bottles for each experiment, four filled with effluents half-saturated with oxygen and four filled with saturated effluents. Duplicate estimations were then made of the oxygen in solution (1) at the time of setting up; and (2) at the end of the period of incubation at 18° C.

A similar set of estimations was done on another (unsettled) Hendon percolation effluent, drawn July 2nd, 1911, while, some six months later, various other determinations of the same kind were made.

The results are given in the table following, four of the seven being done in duplicate by two experimenters:—

TABLE SHOWING THE EFFECT OF CONCENTRATION OF DISSOLVED OXYGEN UPON ITS RATE OF ABSORPTION BY AN EFFLUENT.

Date.	Sample used.	Oxygen at start.	Oxygen at end.	Oxygen taken up.	Length of time sample was incubated (at 18° C. (Days.)	
		Parts	*per* 100,0	00.		
June 30th, 1911	Hendon Percolation Effluent, drawn June 28th.	0·838	0·753	0·087	1	A.C.C
		0·828	0·739			
	" "	0·516	0·396	0·100		
		0·486	0·407			
	" "	0·745	0·667	0·062	1	A.F.G.
		0·716	0·670			
	" "	0·555	0·472	0·068		
		0·538	0·484			
July 4th, 1911	Hendon Percolation Effluent, drawn July 2nd.	0·729	0·373	0·376	1	A.C.C.
		0·743	0·347			
	" "	0·280	0·00	0·280 + *a*		
		0·280	0·00			
July 5th, 1911	" "	0·717	0·339	0·391	1	A.F.G.
		0·737	0·333			
	" "	0·510	0·124	0·392		
		0·510	0·112			
February 2nd, 1912	Composite Effluent (chiefly Hendon)	0·776	0·641	0·135	1	A.C.C.
		0·765	0·630			
		0·574	0·454	0·121		
		0·579	0·452			
March 1st, 1912	Mixed Ealing and Rugby Percolation Effluents; 1 effluent + 4 tap water	0·840	0·620	0·250	5	E.H.R.
		0·855	0·575			
		0·422	0·232	0·203		
		0·415	0·200			
March 20th, 1912	Ealing Percolation Effluent, diluted with $\frac{1}{5}$ its volume of tap water	0·807	0·200	0·579	5	E.H.R.
		0·802	0·252			
		0·560	0·145	0·409		
		0·555	0·152			
	" "	0·785	0·316	0·454	5	A.C.C.
		0·788	0·350			
	" "	0·514	0·140	0·376		
		0·513	0·136			
March 22nd, 1912	Hendon Percolation Effluent, diluted with 3 times its volume of tap water	0·865	0·488	0·375	4	E.H.R.
		0·860	0·490			
		0·565	0·200	0·369		
		0·573	0·200			
	" "	0·854	0·486	0·375	4	A.C.C.
		0·863	0·479			
	" "	0·559	0·206	0·361		
		0·567	0·197			
March 25th, 1912	" "	0·815	0·620	0·200	4	E.H.R.
		0·805	0·600			
	" "	0·280	0·115	0·165		
		0·285	0·120			

These results taken as a whole indicate that, though there is no very material difference, the rate of absorption tends to slacken after the oxygen in solution becomes reduced to about 0·2 part per 100,000, or less. It would be advisable that some further experiments on the same lines should be made.

ADDENDUM B TO SECTION 2.

RATE OF OXIDATION OF NITRITE BY ACID PERMANGANATE, AS CARRIED OUT IN THE DETERMINATION OF DISSOLVED OXYGEN.

It is necessary to allow some time to elapse after the addition of the permanganate, and we have satisfied ourselves by experiment that 20 minutes is sufficient for this. As the point is important, the experiments on which the statement is based may be detailed here.

1. *Preliminary experiment*, made October 9th, 1911, to see whether the products of interaction of sulphuric acid, permanganate, potassium oxalate and water, in the quantities employed in a dissolved oxygen estimation, interfere with the subsequent determination of nitrite in the liquid by means of meta-phenylene diamine.

A solution was prepared of 360 c.c. tap-water, 0·9 c.c. concentrated sulphuric acid, 1 c.c. of $\frac{N}{8}$ permanganate, and enough potassic oxalate to decolorise the permanganate. This solution, when decolorised, was used to make up solutions of potassic nitrite, containing respectively 0·10, 0·05, and 0·02 nitrous nitrogen per 100,000. Solutions of similar concentrations of nitrite were made up with plain acidified tap-water, and were matched against the first series after the addition of meta-phenylene diamine to each.

The solutions made up with acidified water were darker than those made up with decolorised permanganate water in about the ratio 5 : 4. The colour was otherwise the same. By employing, therefore, a decolorised permanganate solution to make up the nitrite standards for the following experiments, error was automatically eliminated.

2. A number of bottles of about 360 c.c. capacity, containing various concentrations of nitrite in tap-water, were each treated at 19°, 15° and 12° C. with 0·9 c.c. concentrated sulphuric acid and 1·0 c.c. $\frac{N}{8}$ permanganate, and were then allowed to stand for 5, 10, 15 and 20 minutes, respectively, before potassic oxalate was added. When decolorised, they were tested for nitrite by meta-phenylene diamine, an otherwise similar solution containing no nitrite being used for preparing the standards. The following results were obtained :—

Length of time Sample remained permanganated before Oxalate was added (Minutes).	Temperature of Sample while permanganated.		
	19° C.	15° C.	12° C.
	Parts Nitrous Nitrogen per 100,000, found.		
5	0·03	0	0
10	0	0	0
15	0	0	0
20	0	0	0

This test can measure down to 0·005 part nitrous nitrogen per 100,000.

3. In two other similar series of experiments, with (*a*) 0·10 and (*b*) 0·05 part nitrous nitrogen added to the water, no nitrite was found in any one instance at the end of 5, 10, 15 and 20 minutes.

Effect of temperature on rate of interaction of permanganate and oxalate in the acid water.—After the addition of oxalate to the permanganated water, the following approximate average times elapsed before the colour of the permanganate vanished completely :—

Temperature - - -	19° C.	15° C.	12° C.
Time required to destroy permanganate - -	4 mins.	13 mins.	21 mins.

4. October 13th, 1911. A percolation effluent containing about 0·20 part nitrous nitrogen per 100,000, was treated in a 360 c.c. bottle with 0·9 c.c. sulphuric acid and 2 c.c. $\frac{N}{8}$ permanganate. After 20 minutes at laboratory temperature, potassic oxalate was added. No nitrite was present.

5. To a percolation effluent potassic nitrite was added in sufficient quantity to bring the nitrous nitrogen up to (*a*) 1·0, and (*b*) 0·5 part per 100,000, respectively, one bottle of each concentration being at a temperature of 14° C. and the other at 19° C. 0·9 c.c. Sulphuric acid and a good excess of permanganate were added, and, after 20 minutes, potassic oxalate. A decolorised "blank" solution was used for the standard. No nitrite was found in any one of the four samples.

6. October 9th, 1911. Two bottles of tap-water at 18° C. were taken, and two bottles of the same water with added nitrite equivalent to 0·10 part nitrous nitrogen per 100,000. The ordinary procedure for the estimation of the dissolved oxygen was then carried out, the solutions being left permanganated for 20 minutes.

The tap-water gave :—

(*a*) 0·840 part oxygen per 100,000.
(*b*) 0·835 part oxygen per 100,000.

The tap-water to which nitrite had been added and then destroyed gave :—

(*a*) 0·840.
(*b*) 0·832.

The end points of the titrations were sharp. This, together with the excellent agreement in results, proved that all nitrite had been destroyed by the procedure.

ADDENDUM C TO SECTION 2.

FURTHER EXAMPLES OF DIFFERENCES IN DUPLICATE ESTIMATIONS OF DISSOLVED OXYGEN ABSORPTION.

Some further examples of differences in duplicate estimations of dissolved oxygen absorption, when the dilutions were other than 1 + 4, may be added here :—

EFFLUENTS.

(*a*) *Dilution with* 2 *volumes tap-water.*—Five pairs of duplicates, incubated respectively for 4, 3, 1, 2 and 1 days, gave an average difference of 0·020 per 100,000 (0·015 to 0·022) of oxygen taken up by the mixture. This is equivalent to an average difference of 0·06 per 100,000, on the undiluted effluent.

(*b*) *Dilution with* 9 *volumes tap-water.*—Four pairs of duplicates, incubated respectively for 6, 5, 5 and 6 days, gave an average difference of 0·010 per 100,000 (0·004 to 0·014) of oxygen taken up by the mixture. This is equivalent to an average difference of 0·10 per 100,000, on the undiluted effluent.

(*c*) *Sewages and tank liquors.*—Dilutions with 49 to 499 volumes tap-water. Nine pairs of duplicates, incubated in each case for 5 days, gave an average difference of 0·020 per 100,000 (0·005 to 0·045) of oxygen taken up by the mixture. This is equivalent to an average difference of 3·34 on the undiluted sewage liquor.

ADDENDUM D TO SECTION 2.

THE ESTIMATION OF DISSOLVED OXYGEN IN AN INCUBATED SAMPLE WHICH CONTAINS MUCH SUSPENDED SOLID.

As is well known, if finely-divided and flocculent suspended solids are present in considerable amount in a liquid in which iodine is to be liberated and then titrated with thiosulphate, the end point of the titration is interfered with, and the titration is rendered inaccurate. In such case, therefore, it is necessary to separate the liquid from the solids before titrating the former.

The bottle containing the 5 days' incubated sample (capacity, say, 350 c.c.) is rotated gently once or twice, so as to ensure the liquid being made homogeneous, and the solids are then allowed to settle again. The liquid is now siphoned into a smaller bottle of known capacity (say, 250 c.c.), which has previously been *filled* with carbon dioxide, a little liquid being allowed to overflow.

The following examples may be cited, as showing the concordance between the figures for oxygen lost on incubation by dilutions of ordinary effluents (*i.e.*, containing no excess of suspended solid), when titrated after incubation: (*a*) direct; (*b*) after siphoning, as above (the direct titrations were done in duplicate):—

Nature of Sample.	Dilution (Vols. tap-water).	Number of Days Incubated.	Dissolved Oxygen lost by Mixture.	
			(*a*) Titrated direct.	(*b*) Titrated after siphoning into CO_2-filled Bottle.
Contact Effluent A. - - -	2	2	·115 ·104	·119
	4	5	·153 ·145	·153
	9	10	·372 ·370	·343
Contact Effluent B. - - -	4	1	·735 ·737	·732
	9	2	·560 ·565	·575
	19	5	·487 ·485	·460

SECTION 3.

(Sections 2, 3 and 9 should be read in conjunction.)

DETERMINATION OF SOLIDS IN SUSPENSION.

(*a*) *Determination of Solids in Suspension in Effluents.*

This is done by passing a given volume of the effluent through a Gooch crucible packed with asbestos.

(1) Preparation of the Asbestos.

The asbestos to be used should be of the quality known as Asbestos floss and should consist of silky but not too fine fibres,* which are cut down, if necessary, to lengths of about 2 cm. A considerable quantity of this is washed with water, to remove palpable dust, and it is then digested with concentrated commercial hydrochloric acid. After another washing with water, it is re-digested with small quantities of pure acid, until the latter is no longer coloured by iron. The asbestos is then thoroughly washed with water until all traces of hydrochloric acid have been removed, and preserved in the state of a rather thick pulp.

(2) Preparation of the Crucible.

The Gooch porcelain crucible employed is about 4·4 cm. (1¾ inch) high by about 3·7 cm. (1½ inch) in diameter at the top, and its weight should not exceed 17 to 20 grammes.

The crucible is fixed into the pressure-filter flask by means of a piece of stout, wide, rubber tubing, about 2·7 to 3 cm. internal diameter and 1.5 cm. in length, which makes an air-tight joint when the pump is in use. Sufficient of the prepared asbestos is then put into the crucible to form a layer which will be ultimately about 0.2 cm. deep. The pump is then turned on and the asbestos spread evenly over the bottom of the crucible, by ramming it with a glass rod flattened out at the end like a small piston rod, a gentle stream of water being run through the crucible all the time. After the asbestos has been well packed, a further quantity of 250 cc. of water is run through the crucible, in order to remove all loose particles of asbestos, and finally a few cc. of distilled water. The crucible is then dried in the hot-air oven at 105° C. (*see* below), ignited, and weighed until the weight is constant. Two, or at most three, weighings should be sufficient to ensure that the last two weighings do not differ by more than 0.0002 gramme.

(3) Filtration of the Sample.

For an average effluent, containing, say, 3 or 4 parts suspended solid per 100,000, a convenient quantity to take for the estimation is 200 cc. It is obvious, however, that—within reasonable limits—the volume to be taken must depend on the amount of suspended solid present. Thus, with an effluent containing 10 parts of solids, 200 cc. would be too much, while with one containing a very small amount it would be too little.

It is desirable that, in all cases involving the possibility of a prosecution, the estimation be done in duplicate, and the mean of the two results taken.

After moistening the asbestos in the weighed crucible with a little of the sample, the pump is turned on very gently, and as much as possible of the liquid is run through under only slightly reduced pressure (a reduction of not more than 100 mm. mercury). This precaution is very necessary if the sample carries much solid, as the latter may clog the filter if a greatly reduced pressure is used in the first instance. It is, therefore, sometimes necessary (*e.g.* when the solids are sticky) to let the bulk of the solid settle before the filtration is begun, so that it may not enter the crucible until the greater part of the liquid is already through.

None of the sample is to be passed more than once through the asbestos. The appearance of the filtrate will at once indicate whether the packing of the asbestos has been well or badly done. The filtrate must always be examined to see that it contains no floating or deposited particles of solid. If it does, the estimation must be rejected and a new one begun.

At the end of the filtration the crucible and its contents are washed several times with small quantities of distilled water, to displace any soluble salts. The crucible is then transferred to the hot-air oven, of temperature 105° C., and weighed once every 24 hours until the weight is constant, say, to within 0.0003 gramme. After this it is ignited at a low red heat and again weighed; this gives the *matter volatile on ignition*. Only one weighing is necessary here.

(4) Precautions in Weighing a Crucible.

It is important that a crucible should not be at a very high temperature when placed in the dessicator. While it must not be allowed to cool in the air so far as to absorb moisture, neither must it be put in so hot as materially to heat the glass of the dessicator, which would then take a long time to cool. A convenient plan is to place the ignited crucibles in the hot-air oven at 105° C, for a few minutes, so that they may take the temperature of the oven. The mass of a dessicator holding seven Gooch crucibles is about 2 kilos, while that of the crucibles is not more than about 140 grammes, hence there will be comparatively little rise in the temperature of the glass. About an hour in the dessicator will then suffice. This procedure has the further great advantage that the weighings of the prepared Gooch crucible, the crucible with suspended solid, and the crucible with ignited solid are all strictly comparable.

In Addenda I.–IV., pp. 105–109, are to be found some details referring to points which bear on the foregoing estimation, viz. :—

In Addendum I :—

Error of the Gooch crucible estimation, when done in blank, i.e., with crucible and asbestos only.

The results of the experiments made upon this point show that:

(*a*) the difference between the penultimate and final weighings of the dried crucible is usually 0.0001 gramme. On 200 cc. of effluent this would represent an error of 0.05 part suspended solid per 100,000;

(*b*) the difference in weight between the dried and the ignited crucible (containing asbestos only) is usually not more than 0.0004 gramme. On 200 cc. of effluent this would represent a plus error of 0.2 part suspended solid and therefore of 0·2 part volatile matter per 100,000.

In Addendum II., p. 105, are given a few examples of duplicate estimations of suspended solids in effluents and in sewage liquors, while Addendum III., p. 106, contains a somewhat larger number of examples, not done in duplicate. In the case of effluents, the difference between the second-last and the final weighings of the dried crucible, with solids, should not exceed 0.0003 gramme. The same thing applies to sewage liquors, provided that the dried solids do not amount to more than about 0.02 gramme; if the quantity is appreciably greater than this, the drying, and therefore the weighing becomes unsatisfactory. Addendum IV. shows the effect of settlement, for 1 and 2 hours respectively, upon a number of typical effluents.

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*We have made enquiry and have been assured by a leading asbestos firm that this quality would always be obtainable, on sufficient notice being given.

(b) *Determination of Solids in Suspension in Sewages and Tank Liquors.*

This is done in exactly the same way as has just been described, excepting that much less of the sample is required in this case. Twenty-five cc. of an average sewage and 50 cc. of an average tank liquor are convenient quantities to take. But here, again, no hard-and-fast rule can be laid down, since the above liquors vary greatly in strength and in suspended solid content.

Twenty-five cc. may appear to be a very small quantity to take of an average sewage (containing, say, 30 parts suspended solids per 100,000), but any disadvantage in this respect, as compared with taking a larger volume, is counter-balanced by the lesser time required to filter the liquor and to dry the Gooch crucible after the filtration, and the consequent lesser risk of loss in weight from the slow distillation of some of the organic solids present. We are indebted to Mr. G. T. P. Tatham's work for this conclusion.

In Section 9, p. 172, specific recommendations are made as to the length of time which may reasonably be allowed to elapse between the drawing and analysis of samples for standard purposes.

COLLOIDAL MATTER.

In the foregoing paper nothing has been said about the solids which are always present in the colloidal state in sewages and tank liquors, and also to a lesser degree in effluents.

Good land effluents may be regarded as free from colloidal matter, and bright sparkling effluents from artificial filters as practically free also. Effluents from contact beds and from percolation filters, however, which show distinct opalescence, contain more or less colloid.

A few years ago we endeavoured to estimate indirectly the colloidal matter in the Gooch filtrates from sewage liquors and effluents of different type, by filtering a known volume of the sewage liquor through a fine-grained porcelain "candle," evaporating the filtrate, drying the residue at 105° C. and weighing. A similar volume of the Gooch filtrate from the estimation of suspended solids was evaporated and dried in the same way, the drying and weighing of each pair of basins being always done together. Lastly, the suspended solids were determined by the Gooch crucible method. The data thus obtained gave an indirect measure of the colloidal matter present in the Gooch filtrate.

This process is, however, a troublesome and tedious one, and by no means perfect, and we have not sufficient results to allow of our saying more than that the Gooch filtrates from ordinary crude sewages and septic tank liquors appear to contain about 3 to 4 parts by weight of colloids per 100,000. The filter effluents examined gave very varying results, and we should not like to venture any opinion at present as to how much colloidal matter different types of effluent contain.

Valuable work on the question of colloidal matter in different sewage liquors has been done by Colonel Jones, Dr. Travis and Mr. J. H. Johnston at Hampton (Jones and Travis, *Proc. Inst. Civil Engineers*, 1905–6; Johnston, *Journ. Royal Sanitary Institute* for 1906); Messrs. O'Shaughnessy and Kinnersley at Birmingham (*Journ. Soc. Chem. Ind.* August, 1906); and Messrs. Fowler, Evans and Oddie (*Journ. Soc. Chem. Ind.*, March, 1908). Mr. Johnston has been kind enough to send to us, in a letter, dated October, 1912, the following table of average* figures for suspended and colloidal matter in the various sewage liquors and effluents at Hampton. The figures for colloids are very high, but it has to be remembered that the sewage at Hampton is unusually strong and, further, that the suspended solids in these experiments were separated by filtration through *soft* filter paper only:—

Colloidal Matter in the Hampton Sewage Liquors, as Measured by Direct Weighing.

PARTS PER 100,000, BY WEIGHT.

	Total Colloidal Matter.	Total Suspended Matter.	Organic Colloidal Matter.	Organic Suspended Matter.
1. In Crude Sewage - - - - - -	12·2	42·3	11·0	28·2
2. „ Hydrolytic Tank Effluent - - - -	8·6	8·3	7·8	4·2
3. „ Primary Contact Effluent - - -	7·6	0·8	7·1	0·7
4. „ Secondary „ „ - - - -	4·7	0·5	4·4	0·4
5. „ Tertiary „ „ - - - -	1·6	0·3	1·5	0·2

Messrs. O'Shaughnessy and Kinnersley measured the suspended and colloidal matters in terms of "oxygen absorbed" from permanganate, albuminoid ammonia, and dissolved solids, and from the results so obtained they made a calculation of the colloidal matter present. The calculated figures obtained show a wide range, according to the source and nature of the sewage liquor, but, speaking generally, this method indicated that the sewages contained something like 2 to 30 parts of colloid; the tank liquors 12 to 20 parts; and the various filter effluents from land, contact beds and percolation filters, respectively, 5 to 9 parts. They found that screening operations followed by the septic tank (*i.e.*, the agitation of the solids in the sewage) tended to increase the colloids in the liquor, while simple settlement reduced them. The colloids in the land effluents were mostly inorganic.

Messrs. Fowler, Evans and Oddie also measured the colloids in terms of "oxygen absorbed." Messrs. Fowler and Ardern, however, in a letter dated October, 1912, inform us that they have recently made some direct estimations (by filtering through a porcelain "candle" and weighing), which indicate that the Manchester sewage contains something like 4 parts of colloidal matter per 100,000.

When a sewage liquor or an effluent containing colloidal matter is discharged into a stream, the ultimate tendency will be for the colloidal matter to aggregate into small but discrete particles, and this to a greater extent, the more obstacles the water meets in its course down stream. Thus, water containing colloids will lose the latter more quickly if the stream is choked with vegetable growth than if it flows over a clean gravelly bottom. On the other hand, the decay of the vegetation will give rise to more colloidal matter.

We think, however, that there can be little doubt that the colloidal matter of a sewage liquor or effluent discharging into a stream must usually travel a long distance in the colloidal state. Therefore, so far as natural purification by the stream is concerned, it must come more into the category of matter in solution than of matter in suspension.

We are satisfied that, excepting perhaps in the case of very highly colloidal sewage liquors, the determination of suspended solids by the Gooch crucible method, as just described, does practically discriminate between the matter in suspension and the colloidal matter plus matter in solution with which the stream has to deal. No doubt, however, in the case of sewages and tank liquors, at all events, the asbestos pad of the Gooch crucible does retain some of the colloids along with the suspended solids proper.

What is really wanted, therefore, for the further elucidation of the subject, is a good and quick direct method for estimating the colloidal, as apart from the true suspended, matter of a sewage liquor or effluent. In view of the comparatively scanty data available, we are inlined to doubt whether the estimates of the amount of colloidal matter present in sewage liquors may not have been somewhat exaggerated.

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* Mr. Johnston says:—"The averages are not from the same number of analyses in each case, being many more in the case of the sewage and tank effluent than in that of the filter effluents; but, as far as possible, I have selected them to make the different samples comparable. . . . I think the table gives an accurate idea of the Hampton samples, according to my methods."

ADDENDUM I. TO SECTION 3.

ERROR OF THE GOOCH CRUCIBLE ESTIMATION, WHEN DONE IN BLANK, *i.e.*, WITH CRUCIBLE AND ASBESTOS ONLY.

The crucibles were made up in the usual way (*cf.* p. 103) and a "solids estimation" was done on 50 c.c. of distilled water.

Weight of Gooch crucible (in grms.) - - -	19·1294	17·3678	19·2559	18·9273	19·8359	19·8527
Weight of crucible plus "solids" (dried at 105° C.) - - - - - - - -	19·1294	17·3679	19·2560	18·9273	19·8359	19·8526
Weight of "solids" - - - - - - -	0·0000	0·0001	0·0001	0·0000	0·0000	0·0001
Weight of crucible (ignited) - - - -	19·1289	17·3673	19·2556	18·9269	19·8355	19·8524
Loss on ignition - - - - - -	0·0005	0·0005	0·0003	0·0004	0·0004	0·0003

ADDENDUM II. TO SECTION 3.

DUPLICATE ESTIMATIONS OF SUSPENDED SOLIDS IN EFFLUENTS AND SEWAGE LIQUORS.

Nature of sample.	Drawn.	Analysed.	Volume taken for estimation (c.c.).	Suspended solids.		Volatile matter in suspended solids.		Appearance of filtrate.
				(*a*)	(*b*)	(*a*)	(*b*)	
Ealing effluent - -	?	Jan. 24th, 1912	200	5·6	5·6	4·5	4·4	
Ealing percolation effluent	July 4th, 1912	July 5th, 1912	200	7·0	8·1	4·4	5·0	Bright and clear.
Accrington percolation effluent - - -	July 8th, 1912	July 9th, 1912	200	2·0	1·8	0·7	0·6	Clear.
Hendon percolation effluent - - -	July 17th, 1912	July 18th, 1912	200	1·9	1·8	1·9	1·8	Trace of turbidity.
Ealing primary contact effluent - - -	July 4th, 1912	July 6th, 1912	100	4·6	5·2	3·5	3·2	Bright and clear.
Hendon primary contact effluent - - -	July 17th, 1912	July 18th, 1912	200	0·5	0·5	0·5	0·5	Trace of cloudiness.
Ealing crude sewage -			25	31·6	32·0	26·4	26·0	
Ealing crude sewage -	July 4th, 1912 (in ice, 6th)	July 8th, 1912	50	26·8	26·6	15·4	16·6	Contained colloidal matter evidently.
Accrington septic tank liquor - - - -	July 8th, 1912	July 9th, 1912	50	7·6	7·4	4·0	3·6	Dark tinted and containing colloidal matter.
Hendon precipitation liquor - - - -	July 17th, 1912	July 18th, 1912	100	2·6	3·0	2·5	2·8	Yellowish and cloudy.

For the sake of further illustration, the various weighings of two of the above determinations may also be given :—

	Ealing effluent.		Ealing crude sewage.			
Volume taken - -	(*a*) 200 c.c.	(*b*) 200 c.c.	(*a*) 25 c.c.	(*b*) 25 c.c.	(*c*) 50 c.c.	(*d*) 100 c.c.
Weight of ignited Gooch crucible - - -	17·3682	18·7720	18·6343	18·6244	18·2538	17·8517
Weight of crucible plus solids dried at 105° C. for 24 hours	17·3794	18·7830	18·6428	18·6327	18·2718	17·8878
,, ,, ,, 48 ,, -	17·3790	18·7826	18·6420	18·6320	18·2706	17·8864
,, ,, ,, 72 ,, -	17·3794	18·7832	18·6422	18·6324	18·2706	17·8849
,, ,, ,, 120 ,, -						17·8842
,, ,, ,, after ignition -	17·3704	18·7744	18·6356	18·6259	18·2577	—
Result :—						
Solids in suspension (per 100,000) - - -	5·6	5·6	31·6	32·0	33·6	—
Volatile matter in those solids (per 100,000) -	4·5	4·4	26·4	26·0	25·6	—

ADDENDUM III TO SECTION 3.

Examples of Estimations of Suspended Solids in Effluents by the Gooch Crucible Method.

Effluent.	Ealing (contact).	Ealing (percolation).	Accrington (percolation).	Rugby (land).	Chorley (percolation).	Lincoln (percolation).	Cambridge (land).	Exeter Belleisle (contact).	Burnley (contact).	Middleton (percolation).	Exeter (septic tank liquor).	Malton (sewage).
When drawn - - - -	Nov. 22, 1911	Nov. 22nd.	Nov. 25th.	Nov. 27th.	Nov. 27th.	Nov. 28th.	Nov. 28th.	Nov. 29th.	Nov. 30th.	Dec. 1st.*	Jan. 13, 1912	Jan. 2nd.
When analysed - - - -	„ 23 „	„ 23rd.	„ 27th.	„ 28th.	„ 28th.	„ 29th.	„ 30th.	„ 30th.	Dec. 1st.	„ 4th.	„ 15 „	„ 3rd.
Volume taken for estimation -	200 cc	200 cc	200 cc	200 cc	200 cc	200 cc	200 cc	200 cc	200 cc	100 cc	50 cc	25 cc
Initial weight of crucible - -	19·2554	18·7536	19·2560	19·8173	17·7178	18·2461	19·7341	19·2584	14·9620	17·3661	19·3256	18·9763
Weight of crucible plus solids dried for 24 hours - - -	19·2621	18·7630	19·2628	19·8202	17·7194	18·2522	19·7414	19·2660	14·9661	17·3737	19·3367	19·0012
Weight of crucible plus solids dried for 48 hours - - -	19·2621	18·7627	19·2627	19·8200	17·7198	18·2525	19·7421	19·2665	14·9659	17·3736	19·3367	19·0014
Weight of crucible plus solids dried for 72 hours - - -	—	—	—	—	17·7199	—	19·7420	19·2662	—	—	—	—
Difference of last two weighings -	0·0000	0·0003	0·0001	0·0002	0·0001	0·0003	0·0001	0·0003	0·0002	0·0001	0·0000	0·0002
Weight of crucible plus ignited solid	19·2560	18·7560	19·2584	19·8180	17·7185	18·2472	19·7374	19·2614	14·9629	17·3682	19·3300	18·9831
Result (parts per 100,000) :— Suspended solids - - -	3·4	4·6	3·4	1·4	1·1	3·2	4·0	3·9	2·0	7·5	22·2	100·4
Volatile - - - - -	3·1	3·4	2·2	1·0	0·7	2·6	2·3	2·4	1·5	5·4	13·4	73·2
Non-volatile - - - -	0·3	1·2	1·2	0·4	0·4	0·6	1·7	1·5	0·5	2·1	8·8	27·2

* The sample was received on the day following this date ; the date of drawing was not actually noted.

ADDENDUM IV. TO SECTION 3.

THE EFFECT OF SETTLEMENT, FOR ONE AND TWO HOURS RESPECTIVELY, UPON TYPICAL EFFLUENTS.

The following table on p. 108 gives the figures for suspended solids, as estimated by the Gooch crucible method, in a number of typical effluents from the treatment of sewage or tank liquor upon land, contact beds and percolation filters. The estimations were done on:—

(*a*) The original sample;
(*b*) The sample after one hour's settlement;
(*c*) The sample after two hours' settlement.

The settlement was effected in half-Winchester quart bottles, about 24 c.m. (9½ inches) high, to the bottom of the stopper, and 10.5 c.m. (4¼ inches) external diameter. Four of the samples were also settled in graduated cylinders, 33 c.m. (13¼ inches) high, to the top of the graduation, and 6 c.m. (2½ inches) internal diameter. The settled samples were siphoned off for analysis at a depth of 12 c.m. (4¾ inches) below the surface of the liquid in both cases.

Of the four samples tested in duplicate, the degree of settlement was the same, whether a bottle or a cylinder was used.

Taking the settlement in half-Winchesters, we get, for the whole of the samples—20 in number:—

Suspended solids.	Min.	Max.	Average.
Original sample - - -	0·5	7·5	2·73
After 1 hour's settlement -	0·5	5·5	1·86
After 2 hours' settlement - -	0·5	4·7	1·69

The effect of settlement for one and two hours upon samples of effluent, containing something like three parts of suspended solid per 100,000, though relatively considerable, cannot be compared to that of filtration. (*Cf.* Tables on pp. 108, 109.)

ADDENDUM IV.—*continued.*

Comparative Settlement, for One and Two Hours, in Half-Winchester Quart Bottles.

Drawn.	Analysed.	Place.	Treatment.	Notes on the effluent.	Original sample.			Sample after one hour's settlement.			Sample after two hours' settlement.		
					Suspended solids.	Volatile.	Non-volatile.	Suspended solids.	Volatile.	Non-volatile.	Suspended solids.	Volatile.	Non-volatile.
Nov. 28, 1911	Nov. 30, 1911	Cambridge	Land	Slightly turbid and containing considerable grey growth	4·0	2·3	1·7	1·7	1·0	0·7	1·6	1·1	0·5
Dec. 6, 1911	Dec. 13, 1911	Croydon	,,	Very slightly opalescent. Sample taken 30 hours after rainfall	0·9	0·6	0·3	0·6	0·5	0·1	0·8	0·7	0·1
Dec. 5, 1911	Dec. 7, 1911	Dewsbury	,,	A thick yellow effluent, colloidal looking	5·7	2·3	3·4	4·6	2·2	2·4	4·6	2·4	2·2
Dec. 4, 1911	Dec. 7, 1911	Leicester	,,	Yellowish in colour, but clear	0·5	0·5	0·0	0·5	0·2	0·3	0·5	0·3	0·2
Nov. 30, 1911	Dec. 1, 1911	Burnley	Contact Bed	Slightly opalescent and brown in colour	2·0	1·5	0·5	2·4	1·6	0·8	1·9	1·3	0·6
Nov. 22, 1911	Nov. 23, 1911	Ealing	,,	Turbid and apparently more or less colloidal	3·4	3·1	0·3	3·0	2·5	0·5	3·2	2·7	0·5
Nov. 29, 1911	Nov. 30, 1911	Exeter (Belle isle)	,,	Brown and turbid	3·9	2·4	1·5	3·9	2·5	1·4	3·4	1·9	1·5
Dec. 5, 1911	Dec. 7, 1911	Manchester	,,	Slightly opalescent and yellowish in colour	1·8	1·1	0·7	1·1	0·6	0·5	0·6	0·2	0·4
Nov. 25, 1911	Nov. 27, 1911	Accrington	Percolation	Dark in colour, with fairly well aggregated solids and some colloidal matter.	3·4	2·2	1·2	1·6	1·2	0·4	1·4	1·2	0·2
Dec. 6, 1911	Dec. 12, 1911	Birmingham	,,	Opalescent	3·2	1·9	1·3	2·2	1·6	0·6	1·8	1·4	0·4
Dec. 13, 1911	Dec. 14, 1911	Blackburn	,,	Slightly opalescent	2·5	1·4	1·1	1·6	1·0	0·6	1·5	1·0	0·5
?	Nov. 28, 1911	Chorley	,,	Slightly opalescent	1·1	0·7	0·4	1·3	0·9	0·4	1·3	0·9	0·4
Dec. 2, 1911	Dec. 4, 1911	Coventry	,,	Brownish in colour	2·8	1·8	1·0	1·7	1·1	0·6	1·4	0·9	0·5
Nov. 22, 1911	Nov. 23, 1911	Ealing	,,	Solids well aggregated	4·6	3·4	1·2	1·3	0·9	0·4	1·2	1·1	0·1
Dec. 15, 1911	Dec. 18, 1911	Enfield	,,	Yellowish and slightly opalescent	1·5	0·6	0·9	1·0	0·5	0·5	0·9	0·4	0·5
Dec. 4, 1911	Dec. 7, 1911	Darwen	,,	Faintly opalescent. Colourless	0·5	0·5	0·0	0·8	0·5	0·3	0·6	0·3	0·3
Dec. 6, 1911	Dec. 7, 1911	Friern Barnet	,,	Slightly opalescent	0·7	0·5	0·2	0·5	0·5	0·0	0·5	0·4	0·1
?	Nov. 29, 1911	Lincoln	,,	Brownish, with brownish-grey solid	3·2	2·6	0·6	1·2	0·9	0·3	0·9	0·7	0·2
Dec. 1, 1911	Dec. 4, 1911	Middleton	,,	Slightly brown in colour and opalescent	7·5	5·4	2·1	5·5	4·3	1·2	4·7	3·7	1·0
Nov. 27, 1911	Nov. 28, 1911	Rugby	,,	Brownish with well aggregated solid. Weather—rain and snow	1·4	1·0	0·4	0·6	0·5	0·1	0·9	0·5	0·4

COMPARATIVE SETTLEMENT FOR 2 HOURS IN HALF-WINCHESTER QUART BOTTLES AND IN CYLINDERS, RESPECTIVELY.

	Original sample.		Half-Winchester.		Cylinder.		
	Suspended solids.	Volatile.	Suspended solids.	Volatile.	Suspended solids.	Volatile.	
Ealing contact effluent	3·4	3·1	3·2	2·7	3·4	2·7	From the top 400 c.c. of 1 litre, taken for settlement.
					3·3	2·8	From the second 400 c.c of 1 litre, taken for settlement.
Ealing percolation effluent	4·6	3·4	1·2	1·1	0·8	0·7	From the top 350 c.c. of 1 litre, taken for settlement.
					1·0	0·8	From the second 350 c.c of 1 litre, taken for settlement.
Exeter (Belleisle) contact effluent	3·9	2·4	3·4	1·9	3·3	2·0	
Lincoln percolation effluent	3·2	2·6	0·9	0·7	0·8	0·7	

SECTION 4.

THE DISCHARGE OF UNPURIFIED SEWAGE OR SEWAGE LIQUORS INTO STREAMS.

Before proceeding to discuss the results obtained at those places where the discharge of unpurified sewage has been under observation for the Commission, it may be useful to set out some of the more general and theoretical considerations relating to this subject.

At first sight the discharge of unpurified sewage into rivers would seem to be not only objectionable in practice but wrong in principle. But so far as the pollution of a river by the influx of " purified " or " unpurified " sewage is concerned, the difference is not one of kind but only of degree. No distinction in principle is, therefore, involved in the admission to a river of either one or the other.

All ordinary sewage effluents are, in fact, mixtures of purified, partially purified and unpurified sewage. A " poor " effluent from percolating filters, contact beds or from land contains a considerable percentage of unpurified sewage, a " good " effluent only a small percentage.

Furthermore, as regards most sewage works the discharge in time of storm of a greater or less amount of either unpurified or only partially purified sewage is inevitable.

A very considerable proportion of the total volume of sewage produced in the British Isles is at present being discharged crude or settled into rivers, often without giving rise to nuisance because of the large dilution with oxygenated water afforded by the stream or river receiving the discharge.

So far as the preservation of the amenities is concerned, dilution with clean water is the chief safeguard against objectionable results of discharge of sewage liquors into rivers. If we except those very high-class effluents, seldom maintained in practice, which will give rise to no objectionable conditions if discharged into a dry ditch, the visible effect of the discharge of much effluent or of a little well screened sewage into a stream is practically the same.

The deterioration in chemical quality of the water is, of course, greater in the case of the discharge of the large volume of effluent even assuming that the proportion of organic impurity is the same in each case, because this mixture contains, of necessity, more salts in solution.

It is to be anticipated that the admixture of a given volume of " purified " effluent of known organic impurity as measured by the " 5 days " dissolved oxygen absorption test would produce a visible effect in a stream less objectionable than that produced by " unpurified " sewage, diluted to give the same figure for that test.

No doubt this is so in fact, but in actual practice the difference would usually be so small as to be inappreciable by the unaided senses.

The impurities of sewage are some in solution, some in suspension.

The rate of intermixture of the dissolved impurities of the sewage with the diluting river water depends on the current velocity of the stream at and below the point of entrance of the sewage, the position of the outfall, the depth of the water, the configuration of the river bed and other physical conditions. It is a comparatively rapid process except where the river is deep and very sluggish.

The distribution throughout the water of the river of the suspended impurities of the sewage depends almost entirely upon the current velocity of the stream below the outfall, and upon the existence of eddies set up by the river bed. It is a very slow process in all rivers except those of high or fairly high current velocity. The larger and heavier particles of suspended matter settle on the bed of the sluggish river or in the pools of the rapid river, and remain there until the current velocity of the water above them is materially quickened, as, for instance, during a flood, when they may be dislodged and carried for a longer or a shorter distance before being re-deposited.

The solids in solution in clean river water are almost entirely inorganic while the suspended solids though partially organic are present in very small amount.

On the other hand, the dissolved and suspended matters of sewage are largely organic and of a nature which renders them liable to undergo decomposition in the presence of water.

It is this decomposition of the more unstable dissolved and suspended organic matter of sewage in the presence of excess of water with which we are particularly concerned.

Since these unstable matters contain a variety of different constituents it follows that their decomposition is not a simple process, although they are finally resolvable into a few simple inorganic substances.

The process of self-purification of a river has, however, been shown to be mainly one of indirect oxidation, through the agency of bacteria, by the oxygen dissolved in the water. The chief effect of this process upon the water is, therefore, the withdrawal of oxygen from solution.

The intermediate products of decomposition arise in the absence of excess of available oxygen, or, in other words, if a sufficient excess of oxygenated water is not present.

Since compounds of sulphur and of phosphorus are always present in sewage impurities, liquid and solid, some of these intermediate products of decomposition have an offensive odour. Certain compounds of nitrogen also come under the same category.

The smells which arise from polluted river water may be classified broadly under the following heads :—

(1) A putrid smell, due mainly to sulphuretted hydrogen.

(2) A fishy smell, due probably to amino-compounds,

(3) A wormy smell, of doubtful origin (? due possibly to compounds of phosphorus).

(4) An earthy smell, due to residual organic substances such as humus.

The earthy and wormy smells are, as a rule, only to be observed on shaking or gently warming the water. In conjunction with the fishy smell they are probably responsible for the stale water smell which is to be noticed in the proximity of rivers in certain states of the atmosphere. Since this stale smell is not usually a strong smell, it is not generally objected to ; it is, indeed, a common one on the river side, and also in marshy districts.

The putrid and fishy smells, on the other hand, may be very strong, and, as they are commonly associated with the decay of animal matter, of dead fish or of human excrement, these are generally objected to.

As we are concerned here with offensive smells alone, the earthy and wormy smells may be dismissed, and only the putrid and fishy smells considered ; the chief object being to ascertain whether any, and, if so, what degree of deoxygenation of water is usually associated with such smells.

Our experience of the facts as between concentration of dissolved oxygen and smell may be summarised as follows :—

Saturation at Ordinary summer river temperatures (says, 7 c.c. of oxygen per litre).—No smell from water unless it be heavily polluted with sewage, when a disagreeable soapy or fæcal smell may be noticed, although high oxygenation is maintained by constant agitation of the water as it flows along the river bed (*Cf.* Part I., Barnoldswick).

Considerable deoxygenation (*say* 3 *c.c. of oxygen per litre at ordinary summer temperatures*).—A fishy smell usually accompanies this condition of oxygenation which, of course, can only obtain in a slow flowing stream which is polluted with a considerable quantity of effluent or a lesser quantity of sewage.

Complete or nearly complete deoxygenation (*say under* 1 *c.c. of oxygen per litre at ordinary summer temperatures*). — A putrid smell of sulphuretted hydrogen usually accompanies this condition of oxygenation.

Waters giving rise to this smell would be denitrified as well as deoxygenated.

Of course the above statements must be taken only in the broadest possible sense, for there are cases where they do not apply. For instance, in the case of the discharge of a considerable quantity of good but deoxygenated effluent into a small stream the concentration of dissolved oxygen in the mixture would be low, though there might be no fishy smell. Again, bubbles of gas, containing sulphuretted hydrogen, may rise through well oxygenated water from putrifying mud at the bottom of a stream and so give rise to local smell. This, indeed, is a common case (*Cf.* Part I., Huntingdon and St. Neots).

The connection between concentration of dissolved oxygen in river water and smell thus only holds good where the deoxygenation has been brought about by more or less prolonged interaction, say, for 24 hours, of the polluting liquid and the water.

It would thus, on the score of nuisance from smell alone, appear inadvisable to allow of the discharge of such volume of polluting liquid as would, by destroying the balance between the rate of deoxygenation and reoxygenation, leave the mixture with less than, say, 4 c.c. of dissolved oxygen per litre at the ordinary temperature. This is 60·3 per cent. of saturation at maximum summer river temperature (65° F.). It would probably be wise in most cases to aim at a higher figure, say, 5·0 c.c. per litre (0·71 parts per 100,000), but for present purposes we may take 4·0 c.c. (0·57 parts per 100,000) as the lowest admissible limit.

If Tables I. and II. of Section 6 of this report (pp 134 and 135), be looked at it will be seen that the average quantity of dissolved oxygen in 28 clean or fairly clean reaches of river (91 samples) was 6·35 c.c. per litre.

The samples, 36 in number, drawn in reaches of "doubtful" condition contained on the average 3·94 c.c. of oxygen per litre.

It would probably be fairly correct, therefore, to assume that, so far as oxygenation was concerned, a reach of river water which usually had as little as 4·0 c.c. of dissolved oxygen per litre was liable to exhibit an unsatisfactory condition.

The rate of reoxygenation, under natural conditions, of water which contains from 4·0 to about 6·0 c.c. of dissolved oxygen thus becomes of interest.

The recent work of Colonel W. M. Black and Professor Earle B. Phelps* makes it possible to arrive at this rate of reoxygenation for *stagnant* water of depths varying from 5 to 20 feet.

In rivers the rate of reoxygenation is influenced mainly by the rate of mixing, which in turn depends upon current velocity, depth of water, configuration of river bed, eddies, etc.

Since these latter conditions vary for different rivers and in different sections of the same river, rates of mixing of waters will vary also. For present purposes it will be useful to take certain different kinds of river reach as broadly typical in each instance of ordinary river conditions.

From a large number of rough tests in rivers and streams with fluorescine, we should say that practically complete mixing of river water with sewage liquor or effluent usually takes place in one or other of the following periods of time :—

Description of River Current.	Approximate Current Velocity of River or Stream.	Approximate time in which mixture becomes complete.
Very rapid -	100 feet or more per minute.	5— 1 min.
Rapid - -	60 to 100 feet per minute.	20—10 ,,
Moderate - -	40 to 60 feet per minute.	90—30 ,,
Slow - -	20 to 40 feet per minute.	3— 2 hours.
Sluggish to very sluggish.	20 feet or less per minute.	6— 3 ,,

From the present point of view the important river reaches are those in which the current velocity is from "moderate" to "very sluggish," and which have water depths of 2 feet 6 inches to 10 feet. These are the common kind of river conditions which allow of serious nuisance arising if the water of the reach is materially polluted.

It will be sufficient, therefore, to confine ourselves to these kinds of river reach.

The following table gives the dilutions, of various sewage liquors and effluents with clean river water, required to prevent deoxygenation of the mixture below 6·0 c.c. (approximately 90 per cent. of saturation at 65° F.) and 4·0 c.c. (approximately 60 per cent. of saturation at 65° F.) per litre.

The figures are deduced from a table very kindly prepared for us by Professor Earle B. Phelps. They have been obtained by calculation from the data for stagnant water given by Colonel Black and Professor Phelps on the assumption that stirring every 1 and 6 hours would give the same reoxygenating effect as the more gradual, though uneven, stirring which occurs in the river naturally.

They are to be looked upon as rough approximations only.

The figures for the 2 feet 6 inches depth of water are based on the further assumption that the rate of reoxygenation at this depth is three times that at the 5 feet depth. This assumption is probably somewhere near the truth.

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* Report of the Massachusetts State Board of Health, Discharge of Sewage into New York Harbour, 1911.

Table Showing Dilutions of Sewage Liquors with Clean River Water Required to Prevent Deoxygenation Below 6·0 and 4·0 c.c. in Moderately Rapid and very Sluggish Reaches.

Depth of water in River. (Feet.)	Time taken for River Water to mix. (Hours.)	Content of dissolved Oxygen in mixture at time of maximum rate of absorption. (c.c. per litre.)	Rate of Reoxygenation of mixture per hour expressed as per cent. of saturation, at 65° F.	Dilution required for			
				(*a*) Strong sewage taking up 20 parts of dissolved oxygen in 24 hours.	(*b*) Average sewage taking up 13 parts of dissolved oxygen in 24 hours.	(*c*) Average septic tank liquor taking up 10 parts of dissolved oxygen in 24 hours.	(*d*) Average precipitation liquor taking up 5 parts of dissolved oxygen in 24 hours.
2·5	1	6	0·24	333	225	265	110
—	—	4	0·99	85	55	40	20
—	6	6	0·12	700	450	340	170
—	—	4	0·45	185	120	90	45
5·0	1	6	0·08	1,000	675	500	250
—	—	4	0·33	250	160	125	60
—	6	6	0·04	2,000	1,250	1,000	500
—	—	4	0·15	550	360	275	135
10·0	1	6	0·03	2,750	1,800	1,375	685
—	—	4	0·12	700	450	340	170
—	6	6	0·02	4,000	2,500	2,000	1,000
—	—	4	0·07	1,200	800	600	300

Note.—Saturation at 65° F. is taken as 6·63 c.c. of oxygen per litre.

The following instances of the discharge of crude and screened sewage and of septic tank liquor have been under observation for the Commission :—

(1) The Malton crude sewage into the Yorkshire Derwent ;

(2) The Pickering crude sewage into the Pickering Beck, a tributary of the Yorkshire Derwent ;

(3) The Ollerton crude sewage into the River Maun, a small branch tributary, *via* the River Idle, of the River Trent ;

(4) The Wye (Kent) crude sewage into the River Stour ;

(5) The Huntingdon very roughly screened sewage into the River Ouse ; and

(6) The St. Neots septic tank liquor into the River Ouse.

We may also include the results from Barnoldswick (land effluent into the Stock Beck, a tributary of the Ribble), as the liquid discharged to the stream from this place in 1909 was more of the nature of a tank liquor than a purified effluent.

The observations have comprised : —

(1) The repeated survey of the river from a point just above the outfall for 2, 3 or sometimes 4 miles down stream ;

(2) An estimate (based on one or another accepted method of gauging) of the ordinary dry weather river flow ;

(3) Riverside determinations of the oxygen in solution in the water ; and

(4) The analytical examination of samples of the sewage discharge and of the river water above and at various points below the sewage outfall.

The detailed results have been given in Part I., but material points relating to each place may be summarised here in tabular form :—

TABLE I.—THE OBSERVED EFFECTS, PHYSICAL AND CHEMICAL, OF THE DISCHARGE OF UNPURIFIED SEWAGE INTO RIVERS.

Place.	Population.	Nature of sewage.	Calculated strength of Sewage. Parts of oxygen taken up per 100,000.	Flow of Sewage in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather, expressed in gallons per 24 hours.	Dilution of Sewage by river water.	River current in ordinary dry weather.	Chemical Analysis.—Parts per 100,000.					Remarks as to observed conditions of the river below the outfall.
									Sewage.	River water above the Sewage outfall.	River water below outfall. Sample drawn at nearest point below outfall. where mixture was complete.	River water below outfall. Sample drawn at farthest point visited below outfall. (1 to 3 miles.)	
Pickering	4,000 (about)	Largely slop water and rather weak.	70	10,000	10,632,000	1,060 to 1	Slow	Ammoniacal nitrogen	3·36	0·003	0·021	0·012	In dry weather unsightly conditions obtained in the eddies just below the sewage outfalls and in these places some smell was also to be noticed. In wet weather these objectionable conditions were absent. In all weathers an appreciable quantity of grey algal growth was to be seen for about half a mile below the outfall, but beyond this there were no marked signs of pollution. Fish were plentiful.
								Albuminoid nitrogen	0·67	0·009	0·018	0·016	
								Nitric nitrogen	0·00	0·16	0·12	0·09	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	7·42				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	3·22	0·19	0·25	0·28	
								Chlorine	5·63	1·58	1·64	1·60	
								Dissolved oxygen taken up from water in 5 days at 65° F.	21·20	0·07	0·15	0·16	
								Oxygen in solution when drawn	0·16	1·04	0·93	1·04	
								Oxygen in solution when analysed	0·00	1·02	0·85	0·99	
								Suspended solids	19·5	0·8	0·8	1·0	
								Number of samples in average	4	4	4	3	
Ollerton	600 (not all draining to river.)	Largely slop water and weak.	40 (about)	8,000	8,000,000	1,000 to 1	Rapid	Ammoniacal nitrogen	0·77	0·052	0·008	0·057	Immediately against the main outfall, at the side of the river, there was a deposit of black putrid mud; but this fouling of the river bed was local, and the river bed was otherwise quite clean below the outfall. Grey growth could be found in fair quantity on one side of the river for a distance of about 250 yards. Green algae were plentiful both above and below the outfall. A large volume of clean spring water joins the river close against the sewage outfall. This accounts for the apparent improvement of the river below the outfall.
								Albuminoid nitrogen	0·24	0·026	0·020	0·026	
								Nitric nitrogen	0·33	0·54	0·55	0·56	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	4·16				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	3·70	0·25	0·19	0·21	
								Chlorine	5·65	3·06	2·99	3·00	
								Dissolved oxygen taken up from water in 5 days at 65° F.	9·87	0·25	0·17	0·17	
								Oxygen in solution when drawn		0·89	0·97	0·99	
								Oxygen in solution when analysed	0·14	0·95	0·99	0·86	
								Suspended solids	14·3	0·85		1·0	
								Number of samples in average	2	4	3	3	
Huntingdon	4,500	Strong domestic with brewery waste	170	100,000	96,000,000	960 to 1	Slow to moderately rapid.	Ammoniacal nitrogen	4·14	0·035	0·022	0·018	There are two sewage outfalls, one large and one small. Below each there was a deposit of putrefying mud which occasionally rose to the surface in dry weather. Grey algal growth was to be observed for about 100 yards below the main and 50 yards below the secondary outfall. Beyond those distances below each outfall no signs of pollution, except small black specks of suspended matter, were to be observed at any time.
								Albuminoid nitrogen	1·44	0·025	0·029	0·030	
								Nitric nitrogen	0·24	0·20	0·25	0·31	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	22·32				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	9·12	0·24	0·25	0·28	
								Chlorine	8·24	2·80	2·78	2·79	
								Dissolved oxygen taken up from water in 5 days at 65° F.	34·20	0·19	0·19	0·20	
								Oxygen in solution when drawn	0·00	0·76	0·71		
								Oxygen in solution when analysed	0·10	0·92	0·89	0·95	
								Suspended solids	1·3	131·3	1·1	1·5	
								Number of samples in average	4	5	4	2	
Wye	800	Domestic of about average strength.	95	12,000	8,250,000	660 to 1	Rather slow	Ammoniacal nitrogen	4·18	0·061	0·065	0·025	There was a deposit of greyish black gritty mud below the outfall, which was partly bared in dry weather or when the river flow was held up artificially. The river bed was somewhat fouled for about 150 to 200 yards, and grey algal growth could be seen for about the same distance, though only in small quantity. The river water was rendered somewhat soapy and turbid. Green water weeds of various kinds flourished above and below the outfall.
								Albuminoid nitrogen	0·95	0·29	0·34	0·036	
								Nitric nitrogen	0·43	0·19	0·22	0·21	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	10·84				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	5·20	0·28	0·27	0·27	
								Chlorine	9·53	2·89	2·87	2·80	
								Dissolved oxygen taken up from water in 5 days at 65° F.	19·61	0·27	0·32	0·24	
								Oxygen in solution when drawn	0·18	0·75	0·86	0·89	
								Oxygen in solution when analysed	0·08	0·79	0·88	0·94	
								Suspended solids	0·9	27·7	1·2	0·7	
								Number of samples in average	9	9	8	6	
Malton and Norton	9,000	Strong domestic with brewery waste	170	300,000	120,000,000	400 to 1	Moderately rapid.	Ammoniacal nitrogen	5·97	0·007	0·017	0·018	There are a number of outfalls. The river bed was considerably fouled below each, and in dry weather black solids rose to the surface of the water. Pieces of fæcal matter could frequently be seen. In wet weather none of the above effects were at all noticeable. Grey algal growth was to be seen in fair quantities for about a mile. Green algae were plentiful in the shallows both above and below Malton.
								Albuminoid nitrogen	1·44	0·016	0·023	0·020	
								Nitric nitrogen	0·13	0·09	0·11	0·10	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	21·05				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	9·85	0·22	0·24	0·25	
								Chlorine	8·67	1·71	1·73	1·67	
								Dissolved oxygen taken up from water in 5 days at 65° F.	52·60	0·13	0·25	0·18	
								Oxygen in solution when drawn		0·88	0·83	0·76	
								Oxygen in solution when analysed	0·00	0·95	0·85	0·74	
								Suspended solids	0·8	48·4	1·9	1·7	
								Number of samples in average	6	6	6	4	

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TABLE II.—THE OBSERVED EFFECTS, PHYSICAL AND CHEMICAL, OF THE DISCHARGE OF UNPURIFIED OR PARTIALLY PURIFIED TANK LIQUORS INTO RIVERS.

Place.	Population.	Nature of Sewage.	Calculated strength of effluent or tank liquor. Parts of oxygen per 100,000.	Flow of Sewage in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather, expressed in gallons per 24 hours.	Dilution of the tank liquor or effluent by river water.	River current in ordinary dry weather.	Chemical Analyses. Parts per 100,000.					Remarks as to observed conditions of the river below the outfall.
									Tank liquor or effluent.	River water above the Sewage outfall.	River water below outfall. Sample drawn at nearest point below outfall, where mixture was complete.	River water below outfall. Sample drawn at farthest point visited below outfall (1 to 3 miles).	
St. Neots	4,000	Domestic with brewery waste Rather strong.	120	100,000	96,000,000	960 to 1	Sluggish	Ammoniacal nitrogen	4·97	0·010	0·012	0·007	Small quantities of grey algal growth were to be seen below the outfall for about 100 yards. In ordinary weather and river conditions there were no other visible signs of pollution. In the deep water against the outfall there was a deposit of suspended matter. In warm weather when the current velocity of the river was very sluggish, or when there were rapid alterations in atmospheric pressure, some of this deposit rose to the surface of the river and caused an objectionable smell.
								Albuminoid nitrogen	1·08	0·026	0·027	0·028	
								Nitric nitrogen		0·24	0·22	0·24	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	14·76				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	5·18	0·28	0·30	0·22	
								Chlorine	14·48	2·54	2·46	2·59	
								Dissolved oxygen taken up from water in 5 days at 65° F.	39·17	0·18	0·24	0·23	
								Oxygen in solution when drawn	0·00	0·89	0·97	0·99	
								Oxygen in solution when analysed		0·93	0·95	0·93	
								Suspended solids	0·8	18·7	0·6	0·8	
								Number of samples in average	5	5	4	3	
Barnoldswick	7,100	Mainly slop water and rather strong	45	150,000	1,500,000	10 to 1	Moderately rapid	Ammoniacal nitrogen	3·88	0·004	0·399	0·315	At the time the observations were made the effect of the effluent discharge was to cause all the ordinary signs of sewage pollution to be present in the beck, both in winter and in summer. For about half a mile below the outfall the bed of the river was coated with putrefying mud and grey algal growth. Owing to the shallowness of the beck and the moderately rapid current velocity, the water was not generally deoxygenated. In spite of this, however, a considerable smell could usually be noticed near the beck for about quarter of a mile or more. Two miles below the outfall all signs of grey growth, foul deposit and smell had disappeared, but in summer time the bed of the beck was here almost choked with green algæ. The volume of the beck at this point is at least three times as large as at the outfall owing to the influx of clean tributary water. Five miles below the outfall, where the volume is about six times as large as at the outfall, trout are plentiful in the beck.
								Albuminoid nitrogen	0·44	0·018	0·09	0·044	
								Nitric nitrogen		0·11	0·09	0·08	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	4·35				
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	2·56	0·20	0·50	0·37	
								Chlorine	6·24	1·11	1·87	1·63	
								Dissolved oxygen taken up from water in 5 days at 65° F.	14·23	0·13	0·97	0·32	
								Oxygen in solution when drawn	0·05	1·01	0·91	1·09	
								Oxygen in solution when analysed	0·00	1·07	0·37	0·85	
								Suspended solids	0·7	8·2	3·3	1·0	
								Number of samples in average	3	3	3	3	

The figures of chemical analysis given in these two tables should be taken as giving no more than a general indication of the degree to which the diluting water is contaminated by a particular discharge of sewage or tank liquor.

The chief reasons for this are :—

(1) Because all the samples (except storm samples) drawn at any particular point on the river are included in the average, irrespective of season, day, time or weather conditions ;

(2) Because the average figures are made up of only a few samples, in some cases only three ;

(3) Because mixture of sewage liquor and diluting water may not always have been complete.

The following points come out quite clearly however :—

1. The discharge of sewage or sewage liquor into a river water of ordinary purity impaired the quality of that water chemically.
2. The river water thus impaired did not revert to its original chemical quality in 1 to 3 miles. It showed, however, distinct signs of recovery at this distance.
3. In every case of crude sewage discharge, local deposits of mud resulted, which were at times offensive. Great dilution to the extent even of 1,000 parts of water to 1 of sewage in a rapid current did not altogether prevent such local deposits.
4. Whether septic tank liquor was discharged into a sluggish stream which diluted it 900 times (St. Neots), or bad effluent was discharged into a rapidly flowing stream which diluted it 10 times (Barnoldswick), local fouling of the river bed occurred with objectionable results.

LIMITING DILUTION FOR SEWAGE.

Beyond this local fouling of the river beds with solid matter and the presence of small quantities of grey algal growth near the outfalls, there were in the case of the discharge of crude sewage at Pickering, Ollerton, Huntingdon, and Wye, no noticeable signs of contamination in the streams receiving the sewage. The dry weather dilution in these four cases ranged from 1 in 660 to 1 in 1,060.

In the case of Malton, where the dry weather dilution was about 1 in 400, and the current velocity only moderately rapid, the fouling of the river bed was more than local, and grey growth could usually be seen for more than a mile below the town.

There are certain considerations to be borne in mind in the case of Malton, however :—

(1) The sewage is discharged from a number of outfalls. This accounts to some extent for the length of river bed fouled with sewage solids.

(2) The waste liquors from two breweries are separately and intermittently discharged into the river. This probably accounts for the presence of grey growth in the river at a distance of over a mile.

In the case of Pickering, also, grey growth may occasionally be seen for about half a mile below the town, although the water at this point is comparatively pure.

The impure liquids discharged into the river at Malton are, however, of a kind common in the case of small market towns, and the broad inference is, we think, that the summer dilution of a very strong sewage to the extent of 1 in 400, with a moderately rapid current velocity, is not quite sufficient to prevent some objectionable signs of contamination becoming noticeable. In winter, when the normal dilution is something like 1 in 600 or 700 and the temperature of the water low, such signs are only to be found by close examination of the river.

If it is assumed that the limiting dilution for a crude sewage of the strength of Malton (170)* is about 1 in 400, then for a sewage of average strength (100)* the limiting dilution should be about 1 in 233. This latter figure, it will be seen, agrees fairly well with that arrived at by calculation on the basis of a 4·0 c.c. dissolved oxygen content, viz., 1 in 160 ; the water being 5 feet deep and the current velocity moderately rapid, *i.e.*, under conditions very similar to those which obtain at Malton.

On the basis of a limiting figure for river waters prescribing that not more than 0·4 parts per 100,000 of dissolved oxygen shall be taken up in 5 days by a mixture of sewage liquor and river water, an average sewage of strength 100 would in the case of a river water taking up 0·2 parts per 100,000 in 5 days require 173 dilutions.

On the basis of a limiting figure of 0·30, 347 dilutions with a 0·20 water would be required.

LIMITING DILUTION FOR TANK LIQUOR.

Only one example of the discharge of tank liquor proper has been under observation and in this case the dilution was as high as 960 to 1 (St. Neots). Apart from the deposition of mud the only noticeable result of the discharge of this very strong tank liquor (strength, 120) was a very small quantity of grey algal growth over a limited area.

In the case of Barnoldswick, where an effluent of such poor quality as practically to come under the category of a tank liquor was diluted with only 10 times its own volume of river water, the stream was badly fouled.

Here the calculated strength of the effluent was 45, and the river water took up, on the average, 0·13 parts per 100,000 of dissolved oxygen in 5 days. From this it may be calculated roughly that a tank liquor of average strength (70) would cause obvious contamination with water taking up 0·20 parts of oxygen in 5 days if the dilution was as low as 1 in 20.

It will be observed that our data on this point are limited, the reason being that we have been unable to find other suitable instances of the discharge of tank liquor into non-tidal reaches. We may, therefore, supplement them by reference to the Channel Experiments (*Cf.* Part III., p. 188).

In these experiments mixtures of the well-clarified Chorley precipitation liquor and town's water were allowed to trickle down V-shaped wooden channels about 80 yards in length. The tank liquor had an average strength of about 33, and took up about 5 parts of dissolved oxygen in 5 days, while the diluting water gave an average figure of 0·15 for dissolved oxygen taken up in 5 days. Two degrees of dilution of the tank liquor were tried, viz., 1 of tank liquor in 9 of water, and 1 of tank liquor in 19 of water.

The condition of both channels was satisfactory until the warmest month, viz., August, of the year during which the experiments were made (1910). At this time the condition of the channel receiving the 1 in 9 mixture might have been called bad, and that of the channel receiving the 1 in 19 mixture doubtful.

The indication was that more than 19 volumes of Chorley town's water were required for 1 volume of Chorley tank liquor in order to prevent noticeable signs of contamination in the channel.

Probably the limiting dilution of the tank liquor with this water might be taken as not less than 1 in 30.

This would be equivalent to a dilution of 1 in 69 for a precipitation liquor of average strength (60) or a dilution of 1 in 91 for a septic tank liquor of average strength (80), with a diluting water which took up 0·20 part of dissolved oxygen in 5 days.

As the depth of water in the channel only averaged about 3 inches, no dilutions based on rate of reoxygenation can properly be compared with these figures. The nearest figures are those given for the 2 feet 6 inches depth, with a 6 hour mixing period and full oxygenation of the water, viz., 1 in 340 for septic tank liquor and 1 in 170 for precipitation liquor.

On the basis of the suggested limiting figure of impurity for river waters (0·40), the dilution, with a water taking up 0·20 parts of dissolved oxygen in 5 days, should be 1 in 73 for a liquor of strength 60 and 1 in 98 for a liquor of strength 80.

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* *Cf.* Fifth Report, Appendix IV.

The dilution figures for tank liquors thus agree fairly well, but having regard to the scantiness of our data we should be disposed to put the safe dilution for a tank liquor of strength 70, *i.e.*, of average strength, at about 1 in 100.

THE DISCHARGE OF SEPTIC TANK LIQUOR INTO RIVERS.

Although sewage undergoes some purification in a septic tank, mainly by deposition of solids, it does not follow that septic tank treatment would necessarily tend to the amelioration of objectionable conditions brought about by a discharge of sewage into a river.

There are formed in a septic tank decomposition products, such as sulphuretted hydrogen, which take up dissolved oxygen from water rapidly. For this reason the improvement effected by the treatment, so far as oxygen content of the river water was concerned, might not be commensurate with the expense involved in the construction of the septic tank.

If the septic tank were large in proportion to the flow of sewage, and if it contained much putrid sludge, the dissolved oxygen absorption in 24 and 48 hours by the tank liquor issuing from it might possibly be greater than that for the sewage entering. In this case it would be better to discharge screened sewage than septic tank liquor, unless, by reason of the rapid flow or shallowness of the river, the rate of reoxygenation of the water immediately below the point of discharge was high enough to counter-balance the rate of deoxygenation of the water occasioned by the septic tank liquor.

When septic tanks are cleaned out at fairly frequent intervals (say, every 3 months), however, and when the rate of flow through the tanks is not unduly prolonged this form of treatment is beneficial from the river point of view. In reducing the suspended matter of the sewage by about 50 per cent. and the total oxidizability by about 25 per cent., it relieves the river of oxidizing work and lessens the chances of objectionable conditions arising from the deposition of suspended matter.

A fixed limit for the suspended matter allowable in septic tank liquors would, we think, effectively prevent septic tanks being used for long periods of time without cleansing.

In the following table are given some examples, for sewages, septic tank and precipitation liquors, of the comparative rates of absorption of dissolved oxygen in 24 hours, 48 hours and 5 days.

Place.	When drawn.	Oxygen absorbed from $\frac{N}{8}$ permanganate "at once."	Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours.	Total Nitrogen (Kjeldahl.)	Suspended solids.	Volatile matter in the suspended solids.	Calculated strength.	Dissolved oxygen taken up from water in						Ratio of 24 hours : 5 days. (24 hours=1.)
								(*a*) 24 hours.	Dilution.	(*b*) 48 hours.	Dilution.	(*c*) 5 days.	Dilution.	
Sewages.														
Huntingdon - -	Dec. 1st, 1909	4·96	27·16	3·58	150·0	47·6	193	10·5	99	16·6	99	29·0	199	1 : 2·8
Malton - - -	June 16th, 1910	3·15	15·47	5·94	30·0	21·8	127	20·2	49	27·8	49	55·4	99	1 : 2·7
,, - - -	Oct 5th, 1910	4·92	20·95	6·24	40·5	28·3	164	19·3	99	23·1	99	39·7	199	1 : 2·1
,, - - -	Feb 8th, 1911	4·28	30·11	15·64	115·4	52·0	266	17·3	49	37·6	49	49·6	99	1 : 2·9
Pickering - - -	June 16th, 1910	1·55	6·00	—	17·8	9·4	—	8·5	99	12·0	99	28·0	199	1 : 3·3
,, - - -	Oct. 6th, 1910	0·54	3·45	1·82	11·4	8·2	30	6·2	49	7·2	49	12·7	99	1 : 2·1
												Average ratio -		**1 : 2·65**
Septic Tank Liquors.														
Exeter (Main Works)	Jan. 13th, 1912	2·11	9·54	4·80	22·2	13·4	84	8·6	24	15·8	49	20·7	99	1 : 2·4
,, (St. Leonards)	Jan. 13th, 1912	2·50	5·61	2·91	7·0	4·0	50	2·3	14	3·1	24	5·0	49	1 : 2·2
Andover - - -	Jan. 12th, 1912	2·05	7·24	5·12	10·0	7·2	70	9·7	24	16·8	49	21·3	99	1 : 2·2
Ilford - - -	Jan. 12th, 1912	1·56	4·62	5·11	3·9	3·5	53	3·2	19	2·9	39	8·9	69	1 : 2·8
Accrington - -	Jan. 13th, 1912	1·13	3·73	2·94	9·2	6·8	37	2·6	24	3·1	49	7·7	99	1 : 2·5
St. Neots - - -	Jan. 9th, 1912	—	11·00	—	—	—	—	13·3	29	14·7	49	24·0	99	1 : 1·8
,, - - -	June 4th, 1910	2·06	7·69	—	13·0	7·5	—	12·2	24	15·9	24	22·3	49	1 : 1·8
,, - - -	Oct. 7th, 1910	4·51	13·81	13·01	14·8	10·6	148	21·9	99	22·5	99	40·6	199	1 : 1·9
												Average ratio -		**1 : 2·20**
Precipitation Liquors.														
Glasgow (Dalmuir) -	Jan. 15th, 1912	0·26	1·59	1·68	4·2	1·7	17	0·9	5	1·2	9	2·3	19	1 : 2·6
,, (Dalmarnock)	Jan. 15th, 1912	1·88	4·36	1·97	2·2	1·6	35	2·4	4	3·6	9	7·2	19	1 : 3·0
,, (Shieldhall)	Jan. 15th, 1912	2·17	5·25	1·70	13·2	9·8	39	2·7	14	3·6	24	6·6	49	1 : 2·4
Normanton - -	Jan. 15th, 1912	1·24	5·66	4·69	12·8	9·2	55	4·7	24	9·3	49	13·8	99	1 : 2·9
Royton - - -	Jan. 15th, 1912	2·25	15·17	4·11	34·0	26·8	110	12·2	24	20·8	49	41·7	99	1 : 3·5
												Average ratio -		**1 : 2·88**

It will be seen from this table that, as compared with the ratio figures for the sewage, the difference between the ratio of the absorption of oxygen in 24 hours to that for 5 days is larger in the case of precipitation liquor but smaller in the case of septic tank liquor.

LIMITS OR STANDARDS OF IMPURITY FOR SEWAGE AND TANK LIQUORS.

It will be seen that both theory and observation lead to the conclusion that the degree of dilution of unpurified sewage liquors required to prevent noticeable signs of contamination in a river depends mainly on the oxygen absorbing power of the liquor and of the diluting water.

A strong sewage requires a larger and a weak sewage a lesser dilution than a sewage of average strength.

Further, the indications are that it is the rate of absorption of oxygen by the dissolved and suspended impurities of the sewage during the first day or so after admixture that governs its ability to cause nuisance, the solid matter which it deposits being largely responsible for the fouling of the river bed and for the further deoxygenation of the water flowing above it.

For determining, therefore, the intrinsic ability of a sewage to produce nuisance, such sewage should probably be subjected to the following tests at least:—

(1) Suspended solids.

(2) Rate of absorption of oxygen by the paper filtered sample in, say, 1, 2, and 5 days.

(3) Rate of absorption of oxygen by the whole sample in, say, 1, 2 and 5 days.

The samples tested would require to be drawn in dry weather, according to rate of flow and over a period of at least 7 consecutive days.

This procedure would have to be carried out for every sewage or sewage liquor. Further, the river flow in dry weather would have to be gauged and its average power of taking up dissolved oxygen in 5 days determined.

It is to be noted that accurate adjustment on the above lines of quantity of sewage to degree of dilution by river water, would, in practice, result in the discharge of the maximum quantity of sewage and sewage liquor into every river.

Probably much unnecessary pollution of rivers and many difficulties of administration could be avoided if certain "limiting dilutions," based upon what is indicated for the strongest sewages and sewage liquors, were made applicable to sewages and sewage liquors of every kind. For example:—

If crude or screened sewage is to be discharged,	The dilution of the sewage by the river water in dry summer weather must reach or exceed 500 volumes to 1.
If sewage liquor (*e.g.*, septic tank liquor or settled sewage) containing not more than 15 parts per 100,000 of suspended matter is to be discharged.	The dilution of the tank liquor by the river water in dry summer weather must reach or exceed 300 volumes to 1.
If well clarified sewage liquor (*e.g.*, precipitation liquor) containing not more than 6 parts per 100,000 of suspended matter is to be discharged.	The dilution of the tank liquor by the river water in dry summer weather must reach or exceed 150 volumes to 1.

The quality of the diluting water would also have to be specified. Probably this would be fixed at about 0·20 part of dissolved oxygen taken up from water in 5 days, no lesser dilution being allowed with water of greater purity. A water taking up 0·4 part of dissolved oxygen in 5 days could not be considered as giving any dilution, since it is, itself, on the verge of causing nuisance; while a water taking up 0·30 part must also be looked upon as of very doubtful quality as a diluent for unpurified sewage or sewage liquor.

In the case of these latter waters, *i.e.*, waters taking up more than 0·20 part of oxygen, we are of opinion that greater dilution should not be required. Otherwise a town would be penalised for the faults of authorities higher up stream.

GRIT SETTLEMENT AND SCREENING BEFORE DISCHARGE.

Since local fouling of the river bed has occurred in the case of every free outfall for sewage or storm water that we have had experience of, and since the same objectionable condition of river bed is common not only with sewage but with sewage liquors and effluents containing a good deal of suspended matter, we think it is safe to conclude that greater or less local fouling of river bed is liable to occur at every outfall, whether for sewage, tank liquor, or effluent.

The discharge of crude sewage into rivers is also liable to result in the noticeable presence in the water of undisintegrated pieces of fæcal matter, garbage, soap, paper, corks, matches, etc., notwithstanding that the dilution afforded by the river water may be far greater than is necessary for the prevention of deoxygenation and nuisance from smell.

Though some signs of contamination will appear at every outfall, whether for sewage, sewage liquor or effluent, it is essential that these signs should be lessened to such an extent as to preclude the possibility of their being objected to.

The position of the outfall in relation to the river flow (*Cf.* Section 10, p. 173) is a matter of great importance, but, as regards crude sewage, settlement of the grit and heavier particles of suspended matter with efficient screening is almost equally important.

It would probably inflict hardship on a small town if the provision of grit tanks and automatic or power-driven screens of fine mesh were to be insisted on for each of its several sewage outfalls, but that all new outfalls should, where practicable, be constructed on these lines we think is very advisable.

The grit tanks should be in duplicate and they should be designed so that the rate of flow through one of them should allow the mineral matters to settle, while the bulk of the organic suspended matters are carried forward to the river.

Since the question of volume of sewage flow is of primary importance with regard to the conditions under which it should be discharged, it is most desirable that the works, where works exist, or, failing that, the tanks, should be designed in such a way as to facilitate accurate gauging and drawing of average samples.

In the case of the discharge of sewage liquors or of effluents, sampling chambers should, we think, be provided in every case as near the actual outfall as questions of fall and other local conditions permit.

SECTION 5.

THE DISCHARGE OF EFFLUENTS INTO STREAMS.

Eighteen cases of the discharge of effluents into streams have been studied.

Since the various streams which have been under observation differ materially in character, volume and rate of flow, any classification of such a comparatively small number, receiving effluents of different quality and different relative volume, must necessarily be on somewhat arbitrary lines.

The rough classification which we put forward in the Interim Streams Report * was according to the calculated strength † or oxidizability of the liquors which they received, thus :—

	Average calculated oxidizability (crediting nitrate).	Number of streams in this group.
Group I.—Sewages and tank liquors ‡ -	50 to 154	7
Group II.—Effluents - -	11 to 18	4
Group III.—Effluents - -	5 to 10	10
Group IV.—Effluents - -	8 to 2	4

Another method of classification is to take the effluents in the order of their figures for dissolved oxygen absorption in 5 days (*cf.* Part II., Section 1, p. 69). This is set out in the following Table A., which also gives the calculated strengths of the effluents (*not* crediting nitrate), the solids in suspension, and the dilution effected.

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* Portions of the Interim Streams Report are given here as Addendum to Part II. of this Appendix, on pp. 177–188.

† *Cf.* Fifth Report, Appendix IV., pp. 1 and 10.

‡ The discharge of sewage liquors has been treated separately in Part II., Section 4 of this Appendix.

TABLE A.

	Effluents.			Stream waters above outfall (¹).	
	Dissolved oxygen absorption in 5 days at 18° C.	Calculated "strength" (including volatile solids, and *not* giving credit for nitrate).	Solids in suspension.	Dissolved oxygen absorption in 5 days at 18° C.	Dilution given by stream.
Tiverton - - - - -	4·57 (11)	16·3 (11)	6·9 (11)	0·18 (3) (²)	200 : 1
Middleton - - - - -	3·94 (11)	21·5 (11)	6·6 (11)	0·14 (3)	1,400 : 1
Swindon - - - - -	2·72 (11)	15·0 (11)	2·4 (9)	0·57 (3)	1 : 1
Nuneaton - - - - -	2·46 (17)	12·0 (17)	2·7 (11)	0·30 (7)	2 : 1
Rugby - - - - -	2·09 (15)	12·8 (15)	2·3 (11)	0·25 (8)	8 : 1
Lincoln - - - - -	1·95 (18)	12·7 (18)	4·6 (16)	0·23 (8)	5 : 1
Berkhamsted - - - -	1·94 (13)	9·2 (13)	2·3 (10)	0·33 (6)	4 : 1
Chelmsford - - - -	1·74 (18)	13·5 (18)	3·9 (18)	0·23 (10)	26 : 1
Hartley Wintney - - -	1·68 (13)	10·3 (13)	3·2 (11)	0·14 (4)	75 : 1
Kenilworth - - - -	1·33 (14)	9·9 (14)	6·6 (14)	0·34 (7)	15 : 1
Alderley Edge - - -	1·28 (15)	8·1 (15)	3·6 (14)	0·28 (5)	9 : 1
Wilpshire - - - -	1·16 (11)	7·2 (11)	3·0 (11)	0·18 (4)	10 : 1
Cambridge - - - -	1·15 (12)	10·2 (12)	2·4 (11)	0·18 (3)	12 : 1
Coventry - - - -	1·00 (19)*	12·9 (19)	2·2 (18)	0·24 (9)	3 : 1
Halstead - - - -	0·79 (7)†	6·3 (7)	2·3 (5)	0·18 (2)	26 : 1
Stratford-on-Avon - -	0·80 (11)	abt. 6·0 (11)	3·0 (8)	0·26 (5)	120 : 1
Consett - - - - -	0·87 (9)	5·0 (9)	3·0 (8)	0·05 (2)	80 : 1
Buxton - - - - -	0·93 (16)	5·1 (16)	2·9 (16)	0·23 (7)	2·5 : 1

(¹) In the case of the stream waters, a few samples have been omitted from the averages, either because they were drawn when the rivers were in flood, or appeared otherwise to be abnormal.

(²) The figures in brackets give the number of samples tested.

* This figure (1·00) is not a true average (*cf.* p. 119).

† This figure (0·79) is not a true average (*see* note, p. 119). Two later samples of effluent from Halstead were more of the nature of sewage, giving, as they did, figures of 13·72 and 16·90 for the 5 days' test. These last two were the only ones drawn at the times when samples of river water were taken, and they are therefore given in Table B.

Either system of classification might be made to serve present purposes, the following considerations being duly borne in mind:—

The 5 days' test gives, in the main, a measure of the carbonaceous matter of a sewage liquor or effluent (*cf.* Part II., Section 1, p. 78), *i.e.*, it takes little or no account of the ammonia present; an important food constituent of river plants and algæ, whose growth helps to purify the water of a stream, while their decay has the opposite effect.

The total oxidizability or "strength" of an effluent, as calculated from the figures of analysis (*cf.* Fifth Report, Appendix IV., p. 12), takes account of the ammonia as well as of the carbonaceous matter, though this ammonia, unless it has time to be completely taken up (before or after oxidation) by vegetation in the stream, may in part reach the sea without being oxidized.

Again, two effluents may be of the same calculated strength, but the one be derived from a strong sewage and the other from a weak one; the latter would take up much the more oxygen in 5 days (*cf.* Table IX. in Part II., Section **1**, p. 66).

Further, two effluents may be of the same calculated strength, but one of them may contain more carbonaceous matter and less ammonia than the other.

The deposition and retention of suspended solids from effluents in slack reaches of streams constitutes, of course, another complicating factor, persistently lowering, as it does, the quality of the water below the effluent outfall.[*]

Perhaps a better, or less faulty, system of classification of effluents in this connection would be to combine the factors of strength and percentage purification. Even then, the nitrate present, another important plant food, would have been left unconsidered in its relation to vegetable growth in the stream.

Reverting to Table A., p. 117, we find that, broadly speaking, the first two systems of classifying the effluents (*i.e.*, according to the 5 days' test and to the calculated strength, not crediting nitrate) agree fairly well. Thus, if we sub-divide, for the moment, the eighteen effluents into three groups, as before, we get:—

	Dissolved oxygen absorption in 5 days.	Calculated strength, (not giving credit for nitrate).
Group I. (4 effluents) - -	2·46 to 4·57	12·0 to 21·5
Group II. (10 effluents) -	1·0 to 2·09	7·2 to 13·5
Group III. (4 effluents) -	0·79 to 0·93	5·0 to 6·3

This group order is much the same as was given in the Interim Streams Report, though the individual arrangement in Group II. is now considerably changed.

Table B., pp. 120–128, deals with the various places of each group in the order of the dilution which the effluent receives. It sets out, for each of the eighteen places concerned, the results of the riverside observations, and also the average figures of analysis of the effluents and river waters. Though certain of the averages in the table are based on comparatively few samples, the general trend of the evidence points, in our view, unequivocally to the following conclusions:—

(1) In every case the results show that the quality of the river water was impaired, though it might be to only a very slight extent, by admixture with the effluent.

(2) In every case signs of pollution were present below the outfall, although with high dilutions these might be hardly appreciable.

The stretch of water below the outfall that was examined, and from which samples were drawn, extended, as a rule, from about 1,000 to 5,000 yards. In no instance within this range, excepting possibly at Rugby and Wilpshire, had the water reverted to its original quality (*i.e.*, the quality above the outfall), but in most cases the lowest drawn sample of a set showed an improvement on the others. At Rugby and Tiverton the water was examined at distances of 13 and 10 miles below outfall, respectively, and in both cases it had recovered its original quality, as regarded organic matter in solution.[‡]

Group I. If we now consider very shortly the effluents of this group (which would usually be regarded as effluents of moderate to poor quality), we find that at Middleton and Tiverton, with dilutions of 1,400 and 200, respectively, by clean streams of rapid current, signs of pollution were present only for a short distance on the outfall side of the river, and in neither case was the water sensibly de-oxygenated. At Nuneaton and Swindon, with dilutions of only 2 and 1, by sluggish and slow streams containing water of poor quality, objectionable conditions were evident for about a mile below the outfalls, and the water was de-oxygenated to a material extent.

In Group II., which comprises ten effluents of fair quality, Hartley Wintney may be considered by itself, the dilution being 75 to 1 by a stream of clean water with a varying current. Here, signs of pollution were practically gone 200 yards below the outfall, and the water was not appreciably de-oxygenated.

At Chelmsford (dilution 26 to 1), Kenilworth (15 to 1), Cambridge (12 to 1), Wilpshire (10 to 1), Alderley Edge (9 to 1), and Rugby (8 to 1), the streams into which the effluents discharge are slow to sluggish, with the exception of Alderley Edge, where the current is fairly rapid.

Signs of pollution—not great at any point—practically disappeared at a quarter of a mile below the outfall at both Rugby and Cambridge, and in neither case was the water seriously de-oxygenated.

At Chelmsford, although the dilution was as much as 26 to 1, and the stream water fairly clean, objectionable conditions, more especially as regards de-oxygenation, were found in the very sluggish reach which extends for about three-quarters of a mile below the outfall. According to calculation (*cf.* Table A., p. 117), the dilution of 1 volume of the effluent with 26 volumes of the river water should have produced a mixture giving an average figure of 0·29 for dissolved oxygen absorption in 5 days, but the actual figure obtained was 0·38. The figures of analysis, therefore, either did not represent the average quality of the effluent discharge, or else the continuous deposition in the slack reach of a rather large amount of suspended solids from the effluent was largely responsible for the deterioration of the water below the outfall. Thus, while the case of Chelmsford is especially interesting in connection with a "limiting figure" for river waters (*cf.* Part II., Section 6, p. 132 *et seq.*), the above discrepancy between expectation and fact does not allow of its being used here as an example.

At both Kenilworth and Alderley Edge, the stream water above outfall was of distinctly poor quality, while at Wilpshire both the quality of the water and the degree of dilution were very variable. It is necessary to allow for these circumstances when interpreting the results obtained at the three places, in none of which was the river below the outfall in what would be called bad condition. At Alderley Edge, grey growth was present in small quantity for about a quarter of a mile below the outfall, while the water was at times distinctly de-oxygenated. At Kenilworth, there was grey growth both above and below the outfall, but rather less below than above, and the water was not appreciably de-oxygenated. At Wilpshire, while there was a fair amount of grey growth for about 100 yards below the outfall, the stream was in a fairly satisfactory condition.

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[*] In Addendum I., p. 129, experimental results are given, showing how far the absorption of dissolved oxygen from water by sewage liquors and effluents is due to the solids in suspension, and how far to the solids in solution; while Part II., Section 8 of this Appendix gives the composition and properties of a number of muds taken from the beds of streams receiving sewage effluents.

[‡] The complete admixture of a sewage or effluent, discharging into a stream, with the stream water itself may, in certain cases, take a long time to effect. Addendum 2., p. 131, shows, however, that the *actual* amount of dissolved oxygen taken up in 5 days by true mixtures of sewage or effluent and stream water agrees with the theoretical.

At Lincoln (dilution 5 to 1), Berkhamsted (4 to 1), and Coventry (3 to 1), the streams which receive the effluents are all of sluggish current, the water being of fair quality at Coventry, but less good in the other cases. The conditions for about a mile below each outfall were not very satisfactory, and the water was distinctly de-oxygenated, especially at Coventry and Berkhamsted. At Berkhamsted, the frequent stirring up of mud by the canal boats must undoubtedly help to de-oxygenate the water (*cf.* Part II., Section 8). At Coventry, the river water was, in dry summer weather, apt to be almost depleted of oxygen, while much grey growth was to be seen. The reason for this was the overworking of the sewage farm at the time, owing to the very rapid increase of population at Coventry (the area of the farm has since been much extended). It should be added here that the figure given in Table A., p. 117, for the Coventry effluent did not represent its average quality about that time; eight further samples drawn within the following month contained practically no oxidized nitrogen, and gave an average figure of 7.0 for dissolved oxygen absorption in 5 days.

In Group III., comprising Stratford (dilution 120 to 1), Consett (80 to 1), and Buxton ($2\frac{1}{2}$ to 1),§ effluents of good quality discharge into clean or fairly clean water; at Stratford the current is sluggish, but rapid at the other two places. In all three there was practically no sign of pollution a quarter of a mile below the outfall, excepting green growth at Buxton, while the water was not appreciably de-oxygenated.

It should be added that although the dilution at Buxton, immediately below the outfall, is $2\frac{1}{2}$ to 1, it increases so rapidly from additions of ground water that it may be double this a few hundred yards lower down.

From a broad review of all the foregoing results, it would appear that, for a sluggish stream, a dilution of not less than 8 to 1 of "clean" water, *i.e.*, water taking up not more than 0·2 part of dissolved oxygen per 100,000 in 5 days (*cf.* Part II., Section 6, p. 136), is required in the case of an effluent of fair quality (taking up not more than 2·0 parts of dissolved oxygen in 5 days), if the stream is to remain free from marked signs of pollution, and its water is not to become materially de-oxygenated. Similarly, a good effluent, taking up—say—1·0 part of dissolved oxygen in 5 days, if discharged into a "clean" stream taking up 0·2 part, would require only about four dilutions; on the other hand, a poor effluent, taking up 4·0 parts of oxygen, would require about sixteen dilutions with water of like quality.

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§ We omit reference to Halstead, because at the time in question night sewage was being discharged into the river; a new purification plant was then in course of construction.

TABLE B.

Group I.—The observed effects, Physical and Chemical, of the Discharge of Effluents into Rivers.

Place.	Population.	Nature of effluent.	Calculated strength of effluents. Parts of oxygen taken up per 100,000.	Flow of effluent in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours.	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical analysis.—Parts per 100,000. The effluent.	River water above the effluent outfall.	River water 200 to 300 yards below the effluent outfall.	River water 1,000 to 1,700 yards below the effluent outfall.	River water 2,000 to 3,000 yards below the effluent outfall.	Remarks as to the observed condition of the river below the outfall.
Middleton in Teesdale	2,160	From percolating filters	21·5	27,500	40,000,000	1,400 to 1	Moderate to rapid	Ammoniacal nitrogen	2·31	0·002	0·005	0·006	—	The sewage outfall is at the side of the river and the effluent is discharged amongst loose stones where there is comparatively little dilution. Amongst these stones for about 50 yards there was a deposit of black putrefying suspended matter and much grey fungus. A slight but distinct smell was observed close to the outfall on one occasion. Three hundred yards below the outfall the mixture of effluent and river water was complete, and from this point onwards there was no sensible sign of pollution. Trout were plentiful both above and below the outfall.
								Albuminoid nitrogen	0·27	0·007	0·009	0·008	—	
								Nitric nitrogen	0·25	0·03	0·03	0·04	—	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	2·61	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 27° C. (80° F.)	—	0·23	0·32	0·20	—	
								Chlorine	3·74	0·60	0·60	0·64	—	
								Dissolved oxygen taken up in 5 days at 18·3° C (65° F.)	3·94	0·14	0·11	0·09	—	
								Oxygen in solution when drawn	—	—	—	—	—	
								Oxygen in solution when analysed	0·06	1·15	1·13	1·19	—	
								Suspended solids	6·6	0·16	—	—	—	
								Number of samples in average	11	3	3	2	—	
Tiverton	10,000	From streaming filters and land	16·3	500,000	100,000,000	200 to 1	Rapid	Ammoniacal nitrogen	1·23	0·003	0·007	0·005	0·010	A considerable quantity of grey algal growth could be seen on the outfall side of the river for a distance of about 250 yards. This was practically the only sign of pollution. In warm weather green algæ were present in small quantities, both above and below the outfall. The river bed is composed of clean stones and rocks almost down to Bickleigh weir, rather more than a mile below the outfall. Trout were plentiful in the water, both above and below the outfall.
								Albuminoid nitrogen	0·26	0·010	0·020	0·011	0·019	
								Nitric nitrogen	0·23	0·09	0·06	0·07	0·07	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	2·45	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	0·10	0·13	0·09	0·12	
								Chlorine	—	1·26	1·19	1·22	1·23	
								Dissolved oxygen taken up in 5 days at 65° F.	4·57	0·18	0·20	0·21	0·23	
								Oxygen in solution when drawn	—	1·07	1·04	1·08	1·04	
								Oxygen in solution when analysed	0·09	1·17	1·04	1·20	1·15	
								Suspended solids	6·87	0·18	2·7	—	—	
								Number of samples in average	11	3	2	2	3	

Place.	Population.	Nature of effluent.	Calculated strength of effluents. Parts of oxygen taken up per 100,000.	Flow of effluent in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours.	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical analysis.—Parts per 100,000.					Remarks as to the observed condition of the river below the outfall.
									The effluent.	River water above the effluent outfall.	River water 200 to 300 yards below the effluent outfall.	River water 1,000 to 1,700 yards below the effluent outfall.	River water 2,000 to 3,000 yards below the effluent outfall.	
Nuneaton	32,000	From percolating filters, contact beds and land	12·0	800,000	1,700,000	2 to 1	Sluggish	Ammoniacal nitrogen	1·48	0·089	0·304	0·216	0·399	The effluent is discharged from three outfalls. There was some old grey algal growth above the outfalls. Just below each of the outfalls there was a strong development of new growth. This extended in moderate quantity for about half a mile below the lowest outfall. At certain seasons of the year green algal growth, duckweed (*Lemna*), etc., were present in great quantities below the outfalls. The algal growth swarmed with aquatic insects. In warm dry weather the water of the river was very dark in appearance. In the sluggish reaches of river below the outfalls there were thin deposits of grey mud, which in warm weather were usually covered with small flies.
								Albuminoid nitrogen	0·19	0·043	0·075	0·064	0·084	
								Nitric nitrogen	1·07	0·03	0·73	0·36	0·49	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	2·20	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	0·39	0·63	0·61	0·61	
								Chlorine	18·35	6·25	8·28	10·74	8·48	
								Dissolved oxygen taken up in 5 days at 65° F.	2·46	0·30	0·61	0·54	0·60	
								Oxygen in solution when drawn	—	0·75	0·56	0·23	0·57	
								Oxygen in solution when analysed	0·32	0·82	0·61	0·38	0·56	
								Suspended solids	2·75	0·97	2·80	—	1·35	
								Number of samples in average	17	7	6	3	4	
Swindon	43,000	From contact beds and land	15·0	1,000,000	1,000,000	1 to 1	Slow	Ammoniacal nitrogen	1·95	0·053	0·289	0·479	0·304	The river water was only fairly clean above the outfall, having already received some sewage effluent. Immediately below the outfall there was a strong development of grey algal growth extending for a distance of more than half a mile, and in many places covering the bed of the river. On one occasion an objectionable smell could be observed near the river for about half a mile below the outfall. No fish were seen between the outfall and Moredon Bridge, a distance of about a mile and a quarter.
								Albuminoid nitrogen	0·22	0·072	0·097	0·106	0·087	
								Nitric nitrogen	0·85	0·28	0·59	0·56	0·67	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·82	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	0·80	1·00	0·90	0·82	
								Chlorine	10·22	2·69	3·31	4·03	3·57	
								Dissolved oxygen taken up in 5 days at 65° F.	2·72	0·57	0·97	1·15	0·82	
								Oxygen in solution when drawn	—	0·72	0·69	0·42	0·88	
								Oxygen in solution when analysed	0·11	1·11	0·78	0·75	0·92	
								Suspended solids	2·35	5·07	6·90	5·93	5·23	
								Number of samples in average	11	3	2	3	3	

TABLE B.—*continued.*

GROUP II.—THE OBSERVED EFFECTS, PHYSICAL AND CHEMICAL, OF THE DISCHARGE OF EFFLUENTS INTO RIVERS—*continued.*

Place.	Population.	Nature of effluent.	Calculated strength of effluent. Parts of oxygen taken up per 100,000.	Flow of effluent in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours.	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical analysis.—Parts per 100,000.							Remarks as to the observed condition of the river below the outfall.
									The effluent	River water above the effluent outfall.	River water 50 to 400 yards below effluent outfall.	River water 500 to 800 yards below effluent outfall.	River water 1000 to 1,700 yards below effluent outfall.	River water 1,500 to 2,200 yards below effluent outfall.	River water 2,500 to 4,000 yards below effluent outfall.	
Hartley Wintney	1,600	From single contact beds and land	10·3	60,000	4,500,000	75 to 1	Slow to rapid	Ammoniacal nitrogen	1·200	0·110	0·025	—	0·024	0·020	—	The effluent does not discharge directly into the river, but flows along a ditch about 150 yards long, in which a considerable deposition of solids takes place. There was a good deal of fungus and black mud in the ditch. As regards the river itself it may be said that beyond small quantities of grey growth near the junction of the ditch little change could be observed below the outfall.
								Albuminoid nitrogen	0·150	0·027	0·022	—	0·023	0·035	—	
								Nitric nitrogen	0·31	0·12	0·12	—	0·10	0·11	—	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·74	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	—	0·36	0·27	—	0·24	0·37	—	
								Chlorine	5·07	1·84	1·87	—	1·88	1·88	—	
								Dissolved oxygen taken up in 5 days at 65° F	1·68	0·17	0·17	—	0·11	0·24	—	
								Oxygen in solution when drawn	—	0·77	0·88	—	0·77	0·80	—	
								Oxygen in solution when analysed	0·34	0·99	0·97	—	0·90	0·91	—	
								Suspended solids	3·23	1·59	0·8	—	0·6	0·8	—	
								Number of samples in average	13	5	4	—	3	4	—	
Chelmsford	16,000	From land	13·5	500,000	13,000,000	26 to 1	Sluggish	Ammoniacal nitrogen	1·53	0·014	0·151	—	0·133	0·097	—	The effluent is discharged into a very sluggish reach of river between two locks. At the time of our observations it altered the appearance of the river very considerably; the water was rendered turbid and of a dark colour; grey fungus was present for about a mile, green algal growth was abundant. The water in this sluggish reach usually swarmed with minute life.
								Albuminoid nitrogen	0·21	0·028	0·045	—	0·047	0·039	—	
								Nitric nitrogen	0·20	0·18	0·20	—	0·20	0·24	—	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	1·80	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	0·28	0·34	—	0·34	0·33	—	
								Chlorine	12·28	3·26	4·19	—	4·07	4·06	—	
								Dissolved oxygen taken up in 5 days at 65° F	1·74	0·23	0·36	—	0·38	0·29	—	
								Oxygen in solution when drawn	—	0·89	0·73	—	0·54	0·72	—	
								Oxygen in solution when analysed	0·14	0·94	0·73	—	0·14	0·74	—	
								Suspended solids	4·00	1·17	1·23	—	1·11	1·90	—	
								Number of samples in average	18	10	8	—	8	7	—	

Kenilworth	4,500	From percolating filters	9·9	100,000	1,500,000	15 to 1	Slow	Ammoniacal nitrogen	0·11	0·037	—	0·032	0·023	0·047	0·046	Grey fungus was usually present on the twigs, grass and stones above the outfall. If anything, the effect of the effluent discharge was to diminish the quantity of fungus in the stream, for this got gradually less from the outfall downwards. A mile below the outfall only traces of fungus were to be seen and two miles below fungus was practically absent. A mile below the outfall the first signs of green algal growth appeared, together with a chocolate-coloured growth, which occurred on most of the stones in the shallows. A green aquatic plant (*Ranunculus aquatilis*) was abundant in the shallows two miles below the outfall. There was no smell. The pools below the outfall contained a good deal of brown-black mud. Small fish were present in the stream.
								Albuminoid nitrogen	0·17	0·045	—	0·037	0·031	0·041	0·041	
								Nitric nitrogen	5·06	0·17	—	0·44	0·43	0·31	0·36	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	2·70	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	0·42	—	0·37	0·34	0·42	0·43	
								Chlorine	32·62	2·33	—	3·38	3·43	2·75	2·76	
								Dissolved oxygen taken up in 5 days at 65° F	1·33	0·34	—	0·36	0·29	0·43	0·43	
								Oxygen in solution when drawn	—	—	—	0·64	0·62	—	—	
								Oxygen in solution when analysed	0·59	0·79	—	0·98	0·82	1·03	0·99	
								Suspended solids	6·62	1·98	—	2·00	2·07	—	—	
								Number of samples in average	14	7	—	3	6	1	1	
Cambridge	55,000	From land	10·2	2,200,000	26,000,000	12 to 1	Sluggish	Ammoniacal nitrogen	1·200	0·048	0·080	0·124	0·145	—	—	The mixing of the effluent with the river water is not complete until about a quarter of a mile below the outfall. A small quantity of grey growth could usually be seen for a distance of about 100 yards, below the outfall, on the outfall side of the river. The water at this side of the river was rendered rather turbid for a somewhat longer distance, and the reeds and rushes were also fouled with floating matter. Beyond these effects little change could be observed as the result of the effluent discharge.
								Albuminoid nitrogen	0·130	0·029	0·038	0·033	0·044	—	—	
								Nitric nitrogen	0·85	0·27	0·32	0·37	0·39	—	—	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	1 06	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	0·21	0·25	0·23	0·22	—	—	
								Chlorine	8·23	2·12	2·42	2·63	2·66	—	—	
								Dissolved oxygen taken up in 5 days at 65° F	1·15	0·18	0·33	0·33	0·45	—	—	
								Oxygen in solution when drawn	—	0·67	0·56	0·70	0·69	—	—	
								Oxygen in solution when analysed	0·13	0·79	0·77	0·75	0·83	—	—	
								Suspended solids	2·37	0·53	0·60	0·65	—	—	—	
								Number of samples in average	12	4	3	3	2	—	—	

TABLE B—*continued.*

GROUP II.—THE OBSERVED EFFECTS, PHYSICAL AND CHEMICAL, OF THE DISCHARGE OF EFFLUENTS INTO RIVERS.

Place.	Population.	Nature of effluent.	Calculated strength of effluent Parts of oxygen taken up per 100,000.	Flow of effluent in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours.	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical analysis.—Parts per 100,000.							Remarks as to the observed condition of the river below the outfall.
									The effluent.	River water above the effluent outfall.	River water 50 to 400 yards below effluent outfall.	River water 500 to 800 yards below effluent outfall.	River water 1,000 to 1,700 yards below effluent outfall.	River water 1,500 to 2,600 yards below effluent outfall.	River water 2,500 to 4,000 yards below effluent outfall.	
Wilpshire	700	From percolating filters and land	7·2	20,000	200,000	10 to 1	Sluggish	Ammoniacal nitrogen	0·780	0·043	0·216	0·067	0·065	—	0·050	For a distance of about 100 yards, below the outfall there was a considerable development of clean, grey fungus, while below this for about a mile the appearance of the stream was slightly deteriorated by pieces of old fungus and a light brown loose deposit of suspended matter. A mile below the outfall there were no sensible signs of pollution. No smell was observed at any part of the stream.
								Albuminoid nitrogen	0·132	0·024	0·058	0·027	0·024	—	0·023	
								Nitric nitrogen	0·25	0·11	0·05	0·14	0·13	—	0·17	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	0·91	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	0·23	0·28	0·26	0·19	—	0·20	
								Chlorine	3·28	1·91	2·83	1·70	1·78	—	1·73	
								Dissolved oxygen taken up in 5 days at 65° F	1·16	0·18	0·19	0·15	0·21	—	0·13	
								Oxygen in solution when drawn	—	1·13	—	—	1·04	—	0·89	
								Oxygen in solution when analysed	0·42	1·13	0·62	1·06	1·26	—	1·17	
								Suspended solids	3·0	0·43	0·80	—	—	—	—	
								Number of samples in average	12	4	1	3	2	—	2	
Alderley Edge	2,950	From streaming filters and land	8:1	100,000	900,000	9 to 1	Fairly rapid	Ammoniacal nitrogen	·680	·045	·254	—	·268	·153	·217	The effect of the discharge was to deteriorate slightly the appearance of the brook for a stretch of about a mile but no farther. Twigs and stones in this reach were covered with a loose brown deposit, and some grey growth was generally present. No smell was observed and there were no signs of offensive deposit.
								Albuminoid nitrogen	·116	·035	·059	—	·039	·037	·051	
								Nitric nitrogen	·40	·16	·19	—	·20	·26	·40	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·19	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	·63	1·06	—	·43	·48	·53	
								Chlorine	6·59	2·27	3·93	—	4·23	3·87	3·85	
								Dissolved oxygen taken up in 5 days at 65° F.	1·28	·28	·51	—	·57	·49	·55	
								Oxygen in solution when drawn	—	·81	·59	—	·49	·58	·44	
								Oxygen in solution when analysed	·22	·89	·46	—	·62	·77	·76	
								Suspended solids	3·64	3·0	6·3	—	1·6	2·1	2·8	
								Number of samples in average	15	5	4	—	4	3	2	

Rugby	21,000	From percolating filters and land.	12·8	530,000	4,500,000	8 to 1	Rather sluggish	Albuminoid nitrogen	0·195	·034	·046	·048	·055	—	·028	lower Rugby outfall a very small stream, called the Sow Brook, joins the Avon. This brook was rather badly polluted at the time of our observations. Notwithstanding this fact no nuisance from smell was observed below the Rugby outfalls and grey growth was practically absent. The river bed was much overgrown with reeds and rushes both above and below the effluent outfalls. At certain seasons of the year there was a great development of green algal growth below the effluent outfalls. Coarse fish were present in the water below the outfall.
								Nitric nitrogen	0·80	·15	·28	·28	·35	—	·32	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	1·81	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	·29	·38	·40	·37	—	·30	
								Chlorine	10·16	2·36	4·05	3·24	3·92	—	3·19	
								Dissolved oxygen taken up in 5 days at 65° F	2·09	·22	·41	·35	·42	—	·19	
								Oxygen in solution when drawn	—	·75	·16	·66	·77	—	·54	
								Oxygen in solution when analysed	·28	·87	·65	·71	·80	—	·72	
								Suspended solids	2·33	·81	—	1·3	·90	—	·26	
								Number of samples to average	15	9	3	7	2	—	4	
Lincoln	47,000	From percolating filters or contact beds	12·7	1,500,000	7,500,000	5 to 1	Slow to sluggish	Ammoniacal nitrogen	1·30	·057	·325	—	·249	·340	·317	Speaking generally, there was no smell below the outfall, but on one occasion, after a period of very dry weather, a slight but distinct smell was observed. The bed of the Delph was considerably fouled with putrescible mud, and in very dry weather when the water was low it had an unpleasant and dirty appearance. Much grey fungus was present below the outfall, and in summer, a mile below the outfall, the development of green algal growth was so great as to impede the flow of water.
								Albuminoid nitrogen	0·20	·040	·086	—	·062	·061	·052	
								Nitric nitrogen	2·11	·234	1·12	—	·82	·71	1·13	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	1·78	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	·39	·63	—	·50	·49	·44	
								Chlorine	14·11	4·54	8·19	—	6·75	6·59	8·23	
								Dissolved oxygen taken up in 5 days at 65° F	1·95	·30	·73	—	·45	·44	·27	
								Oxygen in solution when drawn	—	1·14	·91	—	·73	·83	—	
								Oxygen in solution when analysed	0·54	1·04	·90	—	·77	·74	·88	
								Suspended solids	4·61	1·76	4·9	—	2·4	2·8	—	
								Number of samples in average	18	11	9	—	11	10	2	
Berkhamsted	8,000	From contact beds	9·2	500,000	2,000,000	4 to	Almost stagnant	Ammoniacal nitrogen	0·98	·011	·084	·341	·279	·152	—	The water in the pound had a stale wormy smell on shaking, but there was no smell on the tow-path. Much grey growth was present on the grass at the sides of the canal all the way down to the second lock, and beyond. There was also some green growth in the pound.
								Albuminoid nitrogen	0·15	·036	·044	·071	·051	·040	—	
								Nitric nitrogen	0·30	·23	·23	·16	·18	·26	—	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	1·04	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	·24	·17	·33	·27	·26	—	
								Chlorine	3·88	1·49	1·66	2·26	2·12	1·54	—	
								Dissolved oxygen taken up in 5 days at 65° F	1·94	·33	·33	·36	·34	·33	—	
								Oxygen in solution when drawn	—	·94	·80	·55	·67	·98	—	
								Oxygen in solution when analysed	0·14	·96	·74	·37	·46	·80	—	
								Suspended solids	2·34	2·1	1·5	2·6	·6	·80	—	
								Number of samples to average	13	6	4	3	2	3	—	

TABLE B—*continued.*

GROUP II.—THE OBSERVED EFFECTS, PHYSICAL AND CHEMICAL, OF THE DISCHARGE OF EFFLUENTS INTO RIVERS.

Place.	Population.	Nature of effluent.	Calculated strength of effluent. Parts of oxygen taken up per 100,000	Flow of effluent in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical analysis.—Parts per 100,000.							Remarks as to the observed condition of the river below the outfall.
									The effluent.	River water above the effluent outfall.	River water 50 to 400 yards below effluent outfall.	River water 500 to 800 yards below effluent outfall.	River water 1,000 to 1,700 yards below effluent outfall.	River water 1,500 to 2,600 yards below effluent outfall.	River water 2,500 to 4,000 yards below effluent outfall.	
Coventry	90,000	From land	12·9	2,500,000	7,500,000	3 to 1	Very sluggish	Ammoniacal nitrogen	1·94	·010	·631	—	·484	·577	·481	The admixture of the variable Coventry effluents considerably altered the appearance of the river as far as and below Stoneleigh Abbey. Grey algal growth (*Cladothrix Dichotoma*) was abundant just below both outfalls; it extended for a distance of nearly two miles below the upper outfall. In the deep and very sluggish reach about half a mile below the lower outfall the water in dry weather was very dark in appearance, and at certain seasons of the year it supported innumerable aquatic insects of various kinds and great quantities of green algæ In parts of this very sluggish reach there were large deposits of putrifying mud. A good many dead fish were seen in the reach during warm dry weather, and at such times there was usually an objectionable smell from the river water.
								Albuminoid nitrogen	0·16	·032	·067	—	·074	·075	·072	
								Nitric nitrogen	1·14	·21	·38	—	·25	·31	·36	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F	1·15	—	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F	—	·25	·49	—	·42	·47	·42	
								Chlorine	10·80	4·32	5·60	—	5·10	5·34	4·49	
								Dissolved oxygen taken up in 5 days at 65° F	1·00	·24	·69	—	·63	·74	1·47	
								Oxygen in solution when drawn	—	1·07	·94	—	·41	·27	·72	
								Oxygen in solution when analysed	0·67	1·23	·63	—	·52	·39	·65	
								Suspended solids	2·23	1·19	—	—	·19	1·6	1·6	
								Number of samples to average	19	9	2	—	8	7	4	

Place.	Population.	Nature of effluent.	Calculated strength of effluent. Parts of oxygen taken up per 100,000.	Flow of effluent in dry weather. Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours.	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical Analysis.—Parts per 100,000.						Remarks as to the observed condition of the river water below the outfall.
									Effluent.	River water above the effluent outfall.	River water 100 to 150 yards below effluent outfall.	River water 400 to 600 yards below effluent outfall.	River water 1,000 to 1,500 yards below effluent outfall.	River water 2,700 to 5,000 yards below effluent outfall.	
Stratford-on-Avon	8,300	From percolating filters and land	About 6·0	300,000	36,000,000	120 to 1	Rather sluggish on the average	Ammoniacal nitrogen	0·20	0·024	·024	·010	—	·014	In the effluent channels and on the outfall itself there was usually a considerable quantity of grey algal growth (*Cladothrix Dichotoma*), and the same growth was also present for a hundred yards or so below the outfall on the outfall side of the river. There was also, in summer, a considerable quantity of green algal growth to be seen close to the outfall. These were the only sensible effects of the effluent admixture. Coarse fish were plentiful below the outfall.
								Albuminoid nitrogen	0·10	0·042	·037	·051	—	·029	
								Nitric nitrogen	2·44	0·29	·37	·30	—	·47	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours	1·25	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours	—	·31	·28	·32	—	·29	
								Chlorine	9·33	3·99	4·71	3·84	—	4·7	
								Dissolved oxygen taken up from water in 5 days	0·80	·26	·27	·46	—	·08	
								Oxygen in solution when drawn	—	—	—	—	—	—	
								Oxygen in solution when analysed	0·47	·91	·96	·84	—	·68	
								Suspended solids	3·02	1·82	2·03	—	—	—	
								Number of samples in average	12	5	4	1	—	1	
Consett	9,000	From land	5·0	180,000	15,000,000	80 to 1	Rapid	Ammoniacal nitrogen	0·59	·001	·026	·004	·019	·014	The outfall is at the side of the river in a shallow stoney reach. Grey algal growth was plentiful for a distance of about 100 yards below the outfall, on the outfall side of the river. In dry weather it could be traced for about 300 yards. Green algal growth was also present in moderate quantity below the outfall. There was a deposit of mud against the outfall. These were the only sensible signs of pollution in dry weather. In wet weather the bed of the Derwent was very much fouled with matter brought down by a rivulet which receives not merely the storm sewage from Consett, but also drainage from very large waste heaps at the Ironworks. This rivulet joins the Derwent about half a mile below the effluent outfall.
								Albuminoid nitrogen	0·10	·008	·014	·006	·015	·017	
								Nitric nitrogen	0·27	·02	·10	·03	·04	·07	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours	0·86	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours	—	·09	·16	·12	·15	·13	
								Chlorine	5·04	1·06	1·43	1·03	1·09	—	
								Dissolved oxygen taken up from water in 5 days	0·87	·05	·11	·08	·14	·21	
								Oxygen in solution when drawn	—	·96	·97	·97	·97	—	
								Oxygen in solution when analysed	0·35	1·05	·96	1·02	·97	·91	
								Suspended solids	3·00	—	—	—	—	—	
								Number of samples in average	9	2	2	2	2	1	

TABLE B.—GROUP III.—THE OBSERVED EFFECTS, PHYSICAL AND CHEMICAL, OF THE DISCHARGE OF EFFLUENTS INTO RIVERS—*continued.*

Place.	Population.	Nature of effluent.	Calculated strength of effluent. Parts of oxygen taken up por 100,000.	Flow of effluent in dry weather Gallons per 24 hours.	Flow of river in ordinary dry weather. Gallons per 24 hours.	Dilution of effluent by river water.	River current in ordinary dry weather.		Chemical Analysis—Parts per 100,000						Remarks as to the observed condition of the river water below the outfall.
									Effluent.	River water above the effluent outfall.	River water 100 to 150 yards below effluent outfall.	River water 400 to 600 yards below effluent outfall.	River water 1,000 to 1,500 yards below effluent outfall.	River water 2,700 to 5,000 yards below effluent outfall.	
Halstead	6,500	from land	—	150,000	4,000,000	26 to 1	Sluggish	Ammoniacal nitrogen	3·310	·020	·090	·130	·152	—	In wet weather all surface water from the streets is carried directly into the river a mile above the outfall, so that on these occasions there is considerable pollution from surface water alone. The water apparently recovers rapidly from such occasional pollution. The appearance of the Colne below the Halstead outfall was, at the time of our observations, considerably deteriorated, owing to the discharge into it of unpurified sewage at night and in times of storm. The water was rendered turbid and opalescent, and there were deposits of putrifying mud for some little distance below the outfall. Green algal growth was present in quantity below the outfall.
								Albuminoid nitrogen	0·71	·021	·026	·053	·079	—	
								Nitric nitrogen	0·00	·33	·42	·31	·16	—	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours	8·55	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours	—	·20	·22	·33	·46	—	
								Chlorine	10·82	3·21	3·50	3·53	3·55	—	
								Dissolved oxygen taken up from water in 5 days	15·31*	·18	·20	·49	—	—	
								Oxygen in solution when drawn	—	·67	—	·35	·36	—	
								Oxygen in solution when analysed	0·00	·88	1·02	·63	·20	—	
								Suspended solids	24·2	—	—	—	—	—	
								Number of samples in average	2	2	1	2	1	—	
Buxton	10,000	From percolating filters	5·1	1,000,000	2,500,000	2½ to 1	Very rapid	Ammoniacal nitrogen	0·15	·055	·061	—	·024	·008	The stream is not always quite clean above the outfall. Immediately below the outfall grey growth coated the bed of the stream, extending for a distance of about 100 yards. At this distance much spring water joins the stream, and the grey growth tailed off so rapidly as to be practically absent 150 to 200 yards farther on. There was a good deal of brownish grey deposit on the stones for about a mile below the outfall. Very large quantities of water-weeds, mainly *Ranunculus Aquatilis*, were always present below the outfall; they extended for several miles, completely carpeting the river bed in many places. No fish were observed for a distance of more
								Albuminoid nitrogen	0·077	·017	·021	—	·023	·015	
								Nitric nitrogen	1·21	·12	·20	—	·24	·22	
								Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours	0·79	—	—	—	—	—	
								Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours	—	·15	·16	—	·11	·13	
								Chlorine	3·12	1·23	1·29	—	1·28	1·09	
								Dissolved oxygen taken up from water in 5 days	0·93	·23	·29	—	·20	·16	
								Oxygen in solution when drawn	—	·93	·88	—	·86	·91	
								Oxygen in solution when analysed	0·65	1·04	·77	—	·83	1·02	
								Suspended solids	2·86	1·5	1·7	—	1·6	2·4	
								Number of samples in average	16	7	4	—	5	4	

ADDENDUM I. TO SECTION 5.

Comparison, as regards power of taking up Dissolved Oxygen by Sewage Liquors and Effluents, of (*a*) the Liquor or Effluent with its Suspended Solids; (*b*) the same Liquor or Effluent after Filtration through Swedish Filter Paper.

The following estimations were made in order to gain an approximate idea of how far the absorption of dissolved oxygen from water by sewages and effluents, in periods up to five days, is due to the solids in suspension and how far to the solids in solution (the latter including, of course, some of the colloidal matter present).

The solids in suspension were estimated in the ordinary way by filtration through asbestos in a Gooch crucible. Had they been done by filtration through Swedish paper, some of the figures obtained might have been slightly, though we think not materially, different.

The results just referred to are given in the following Table A.* This table gives—

(1) The number of samples tested in this way from each place.

(2) The average figures for suspended solids in those samples.

(3) The average figures for dissolved oxygen absorption in 24 hours, 48 hours, and 5 days, for both the original and the paper-filtered samples.

(4) The average percentage reduction in the dissolved oxygen absorption, the figure for the sample containing suspended solids being taken at 100.

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* The arrangement in Groups II., III. and IV. of this table (the greater part of which was put together for the Interim Streams Report in the Spring of 1910) is not quite the same as that in Table A., p. 117. As this is however immaterial for the purpose of the present Addendum, it has not been thought necessary to make any alteration.

Table A.

Place.	Number of samples examined.	Suspended solids.		Dissolved oxygen absorption at 18° C. in—					
				24 hours.	Percentage reduction.	48 hours.	Percentage reduction.	5 days.	Percentage reduction.
Group I.									
Pickering - - -	4	26·4	Original sample	9·8	51	15.2	57	26·9	58
			P.f.[1] ,,	4·8		6·5		11·1	
St. Neots - - -	5	19·4	Original ,,	11·3 (4)*	16	14·3	26	22·8	22
			P.f. ,,	9·5 (4)		10·6		17·7	
Huntingdon - -	3	59·4	Original ,,	21·7	50	35·5	55	67·2	65
			P.f. ,,	10·8		16·1		23·4	
Malton - - -	4	48·9	Original ,,	22·9	57	32·6†	54	64·0†	59
			P.f. ,,	9·8		14·9		26·3	
Barnoldswick - -	4	9·8	Original ,,	6·2 (3)	37	9·6	48	18·4	42
			P.f. ,,	3·9 (3)		5·9		10·6	
Group II.									
Middleton - - -	4	5·7	Original ,,	·48 (3)	21	1·34	49	4·02	63
			P.f. ,,	·38 (3)		·69		1·49	
Rugby - - -	4	0·9	Original ,,	·15 (3)	33	·28	7	1·65	52
			P.f. ,,	·10 (3)		·26		·79	
Swindon - - -	4	2·2	Original ,,	·81	47	1·27 (3)	35	4·13	51
			P.f. ,,	·43		·82 (3)		2·00	
Tiverton - - -	4	5·0	Original ,,	1·97 (3)	23	3·39	36	5·79	39
			P.f. ,,	1·51 (3)		2·18		3·54	
Group III.									
Consett - - -	3	2·3	Original sample	—	—	0·71 (2)	52	1·08	52
			P.f. ,,			0·34 (2)		0·52	
Hartley Wintney -	4	2·8	Original ,,	0·35 (3)	60	0·78	64	1·94	68
			P.f. ,,	0·14 (3)		0·28		0·61	
Chelmsford - - -	3	4·2	Original ,,	0·79 (2)	18	1·10	34	2·73	42
			P.f. ,,	0·65 (2)		0·73		1·58	
Berkhamsted - -	2	2·6	Original ,,	1·24	11	2·31	23	4·27	30
			P.f. ,,	1·10		1·77		2·99	
Wilpshire - - -	4	2·1	Original ,,	0·37 (3)	59	0·88	64	1·75	52
			P.f. ,,	0·15 (3)		0·32		0·83	
Cambridge - - -	4	2·0	Original ,,	0·26	54	0·31	42	0·93	48
			P.f. ,,	0.12		0·18		0·48	
Alderley Edge - -	3	2·2	Original ,,	0·17 (2)	47	0·80†	46	1·86	55
			P.f. ,,	0·09 (2)		0·43		0·83	
Lincoln - - -	5	2·1	Original ,,	0·12 (4)	83	0·30	73	1·45	74
			P.f. ,,	0·02 (4)		0·08		0·41	
Nuneaton - - -	5	2·1	Original ,,	0·16 (4)	69	0·39	62	1·66	80
			P.f. ,,	0·05 (4)		0·15		0·33	
Coventry - - -	5	2·3	Original ,,	0·18 (4)	72	0·23	56	0·59	42
			P.f. ,,	0·05 (4)		0·10		0·34	
Group IV.									
Stratford - - -	5	2·7	Original ,,	0·38 (4)	45	0·67	49	1·78	63
			P.f. ,,	0·21 (4)		0·34		0·67	
Kenilworth - - -	5	5·5	Original ,,	0·12 (4)	75	0·29	79	0·86	59
			P.f. ,,	0·03 (4)		0·06		0·35	
Buxton - - -	5	2·6	Original ,,	0·10 (3)	50	0·16	37	0·65	54
			P.f. ,,	0·05 (3)		0·10		0·30	

[1] P.f. = "paper-filtered." * The figures in brackets indicate the number of samples, when these were less than the number given in column 2. † Oxygen exhausted in one instance.

GROUP I. (5 places).

The average percentage differences between the figures for dissolved oxygen absorption in (*a*) the original and (*b*) the paper-filtered samples were fairly even in four out of the five cases.

In each of the five cases, taken by itself, the percentage reductions were practically the same in 24 hours, 48 hours, and 5 days.

The average percentage reduction figures for the whole group were:—

Percentage reduction for 24 hours - 42
" " 48 " - 48
" " 5 days - - 49

In other words, the average figures for dissolved oxygen absorption by the original and the paper-filtered samples of the sewage liquors comprising this group were approximately as 1 : 0.5.

A sewage or sewage liquor containing an average of about 35 parts of suspended solids will therefore take up about twice as much dissolved oxygen in either 24 hours, 48 hours, or 5 days, as the same liquor after its suspended solids have been removed by filtration through Swedish filter-paper.

GROUP II. (4 places).

The average percentage differences between the figures for dissolved oxygen absorption in (*a*) the original and (*b*) the paper-filtered samples were less even in this group than in Group I. Excepting, however, for the apparently anomalous average result in the 48 hours' figures for Rugby (the actual figures themselves being low), there is again a fair agreement throughout this group as a whole.

In the four cases, taken by themselves, the percentage reductions in 24 hours, 48 hours and 5 days did not agree well in the cases of Middleton and Rugby, but they did in those of Swindon and Tiverton.

The average percentage reduction figures for the whole group were:—

Percentage reduction for 24 hours - 31
" " 48 " - 32
" " 5 days - - 51

Thus, the average figures for dissolved oxygen absorption by the original and the paper-filtered samples of the effluents of this group were as 1 : 0·66 in 24 and 48 hours, and 1 : 0·5 in 5 days.

An effluent of medium to rather indifferent quality, therefore (so far as can be judged from a small group), containing an average of about 3.5 parts of suspended solids, will take up about one and a half times as much oxygen in 24 and 48 hours, and about twice as much in 5 days, as the same liquor after its suspended solids have been removed by filtration through paper.

GROUP III. (10 places).

The average percentage differences between the figures for dissolved oxygen absorption in (*a*) the original and (*b*) the paper-filtered samples showed a wonderfully good agreement, excepting in the case of Chelmsford and Berkhamsted, and even there the disagreement was mainly in the 24 hours' figures.

In each of the 10 cases, taken by itself, the percentage reductions were—broadly speaking—much the same in 24 hours, 48 hours, and 5 days.

The average percentage reductions for the whole group were:—

Percentage reduction for 24 hours - 53
" " 48 " - 52
" " 5 days - - 54

In other words, the average figures for dissolved oxygen absorption by the original and the paper-filtered samples of the effluents comprising this group were as 1 : 0·5.

An effluent of fair quality, therefore, containing an average of about 2·5 parts of suspended solids, will take up about twice as much dissolved oxygen in 24 hours, 48 hours and 5 days, as the same liquor after its suspended solids have been removed by filtration through paper.

GROUP IV. (3 places—Stratford, Kenilworth and Buxton).

The average percentage differences between the figures for dissolved oxygen absorption in (*a*) the original, and (*b*) the paper-filtered samples were again fairly even here.

In each of the 3 cases, taken by itself, the percentage reductions were not very different in 24 hours, 48 hours, and 5 days.

The average percentage reduction figures for the whole group were:—

Percentage reduction for 24 hours - 57
" " 48 " - 55
" " 5 days - - 59

In other words, the average figures for dissolved oxygen absorption by the original and the paper-filtered samples of the effluents comprising this group were approximately as 1 : 0.4 in 24 hours, 48 hours, and 5 days.

An effluent of good quality, therefore, containing an average of about 3·5 parts of suspended solids, will take up rather more than twice as much dissolved oxygen in 24 hours, 48 hours, and 5 days, as the same effluent after its suspended solids have been removed by filtration through paper.

In reviewing the foregoing figures, it has to be borne in mind that they are all averages, each one of them from a comparatively small number of samples. Still, the aggregate number of samples is large, viz.:—

In Group I. - - - - 20 samples.
" II. - - - - 16 "
" III. - - - - 38 "
" IV. - - - - 15 "
Total - - - - 89 "

The conclusions drawn are probably, therefore, fairly correct. Hence, we think it may be taken that sewage liquors and effluents generally, with their suspended solids, will take up about twice as much dissolved oxygen, in periods up to 5 days, as the liquid portion alone will do.

ADDENDUM 2 TO SECTION 5.

Comparison of the Actual Absorption of Dissolved Oxygen by known Mixtures of Sewage or Effluent and River Water with the Theoretical Absorption.

It was thought advisable to make a few determinations in the laboratory of the amounts of dissolved oxygen taken up in 5 days by (*a*) a sewage or effluent; (*b*) the actual river water into which this would discharge (as distinguished from the tap water ordinarily used for diluting in the laboratory); and (*c*) a definite mixture of (*a*) and (*b*); in order to ascertain how nearly the figure of (*c*) coincided with the figure obtained by calculation from (*a*) and (*b*).

The dilutions made varied from 4 to 400—a wide range—and they were arranged so that the anticipated figure for the 5 days' test should approximate to that which would naturally be obtained from river water in clean, or fairly clean, condition.

Eight sets of estimations were therefore done, four with sewage liquors and four with effluents, and the results are set out in the table below. The figures given in this table, for dissolved oxygen absorption by sewages and effluents, river waters, and mixtures of sewage or effluent with river water, are in every case the mean of two closely agreeing duplicates.

Table showing the Actual and also the Calculated Absorption of Dissolved Oxygen in 5 Days at 18° C. by known Mixtures of Sewage or Effluent and River Water.

Results expressed in parts per 100,000 by weight.

(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)
	(1) Sewage liquors.		River waters.	Mixture of sewage and river water.			
Samples drawn from:—	Dissolved oxygen taken up by sewage from tap water in 5 days at 18° C.	Dilution given (vols. tap water).	Dissolved oxygen taken up by river water in 5 days at 18° C.	Volume of sewage in mixture.	Volume of river water in mixture.	Dissolved oxygen taken up by mixture in 5 days at 18° C.	Theoretical absorption, as calculated from Columns (*b*) and (*d*).
Malton, January 2, 1912	120·8	149	0·06	1	400	0·38	0·39
Pickering, January 2, 1912	([1])	—	0·06	1	250	0·54	0·55
Wye, January 2, 1912	8·1	24	0·17	1	149	0·21	0·22
St. Neots, January 10, 1912	25·2	49	0·06	1	250	0·18	0·16
	25·7	99	—	—	—	—	—
	(2) Effluents.		River waters.	Mixture of effluent and river water.			
Middleton, December 29, 1911	1·55	9	0·04	1	9	0·15	0·19
Tiverton, December 29, 1911	3·83	9	0·03	1	29	0·03	0·16
Hartley Wintney, January 4, 1912	1·09	4	0·11	1	25	0·15	0·14
Chelmsford, January 16, 1912	1·18*	9	0·17*	1	25	0·29*	0·21

Sewage Liquors.—Of the two sewages experimented with, that from Malton was exceptionally strong, while the one from Wye was very weak; the tank liquor from St. Neots was of about average strength. As regards the respective river waters, those from Pickering, Malton and St. Neots were of excellent quality, while that from Wye represented an ordinary "clean" stream (*Cf.*, Part II., Section 6, p. 136). It will be seen from the table that in every case the amount of dissolved oxygen taken up in 5 days was, within error of experiment, the same as that calculated from the figures given by the sewage liquor and the river water separately.

Effluents.—Three of these were of good or fair quality, while the fourth was rather poor; three of the river waters were good or very good, the fourth being fair. The table shows that in three of the four instances there was good or fairly good agreement between the actual figure found for dissolved oxygen absorption by the mixture of effluent and river water and the calculated figure, while in the fourth case (Tiverton) the agreement was not good. It has, however, to be borne in mind that—apart from a possible slip in this estimation—the figures themselves represent very small amounts of oxygen, so that the difference between the two discordant figures, 0·03 and 0·16, though relatively great, is in reality small.

Taking the whole results together, therefore, there can be no reasonable doubt that when a sewage liquor or effluent of known quality as regards the taking up of dissolved oxygen discharges into a stream, also of known quality in this respect, the mixture of the two will yield the theoretical or nearly the theoretical, result when subjected to the 5 days' test.

While it is easy, however, to obtain in the laboratory *complete* admixture of sewage or effluent and diluting water, it is by no means so easy in the stream itself (even though we leave out of account here the question of the absorption of carbonaceous and nitrogenous matter by aquatic plants, etc., and other disturbing factors). Hence, it would be unreasonable to expect the same degree of concordance in the samples drawn from a polluted stream as in those made up in the laboratory to represent such a stream.

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[1] No Sewage (but only river water) could at that time be sent from Pickering, so the Malton sewage was taken for dilution with the Pickering river water. * Six days.

SECTION 6.

LIMITING FIGURES OF IMPURITY FOR RIVER WATERS.

As the result of repeated surveys of the rivers and streams which have been under observation for the Commission, we find that the general visible conditions of the various reaches of river can be classified, very broadly, as follows :—

Very Clean.—The water is clear, bright and odourless ; fish of the more delicate kind, such as salmon and trout, may be plentiful in the pools ; the bed of the river, whether composed of rocks, sand or mud, is everywhere quite clean and for the most part bare ; diatoms are plentiful, but water weeds and green algæ are comparatively scarce.

The following reaches of rivers may be mentioned as examples :—

The Tees at Middleton.
The Exe above Tiverton.
The Pickering Beck above Pickering.

Clean.—The water is clear and bright. It is either odourless or it emits only a faint earthy smell on being shaken in a bottle.

Fish, such as trout and grayling, may or may not be present, but the coarse varieties are plentiful.

The stones in the shallows are clean, but a fine, light brown deposit is to be seen on those lying in the pools.

Water weeds are plentiful and their fronds are, except perhaps in late autumn, fairly clean looking. Moderate quantities of green algæ are to be seen in all the shallows.

The following examples may be cited :—

The Ouse at St. Neots and Huntingdon.
The Yorkshire Derwent just above Malton.
The Essex Colne above Halstead.
The Warwickshire Avon between Wolston and Baginton.

Fairly Clean.—Under this head we place rivers or streams usually clean, but liable at times to be rather dirty looking.

The water is clear but slightly opalescent. It emits a pronounced earthy odour on shaking in a closed bottle. Probably none but coarse fish are present.

The stones lying in the pools as well as in the shallows are lightly coated with a brown fluffy deposit.

Water weeds are plentiful ; their fronds are fairly clean but brown-coloured in places ; their stems are covered with fluffy deposit.

Green algæ are plentiful in the shallows.

The following examples may be cited :—

The Kentish Stour at Olantigh Park.
The Avon at Warwick Castle.

Moderately Clean.—The water is distinctly opalescent, but otherwise fairly clear. It emits an earthy or earthy-wormy smell on being shaken in a bottle.

Coarse fish are usually present.

The stones in the shallows are coated with brown or dark green matter, and this matter is seen to be organised on examination with the naked eye, *i.e.*, it is distinctly filamentous and does not at once become disseminated when scraped off into the water. The stones lying in the pools are covered with a layer of brown deposit.

Water weeds of many kinds are abundant. In the slacker reaches the larger fronds are unhealthy looking, and they are covered with a light brown fluffy deposit.

Green algæ are plentiful if not abundant, and they contain many aquatic insects.

The following examples may be cited :—

The Cam below Baits Bite lock at Cambridge.
The Finham Brook below Kenilworth.
The Kentish Stour just below Wye.

Doubtful.—The water is slightly turbid with finely-divided suspended matter ; it is noticeably opalescent ; it emits a strong earthy-wormy smell on being shaken in a bottle. In summer time this smell may occasionally be noticed near the river.

It has a black appearance in the pools.

Though fish of any size are exceedingly scarce, swarms of tiny fry are to be found in small pools protected from the main current.

All stones, weeds and twigs are coated with brown fluffy matter which is distinctly filamentous in appearance.

Water weeds are plentiful, especially duck-weed in sluggish streams and at certain seasons of the year. The stems of the larger weeds, and sometimes their fronds, are covered with fluffy brown filamentous matter and are festooned with green algæ.

Green algæ, more particularly one with very fine filaments of a deep green colour, abound wherever opportunities are afforded for their lodgment and development. This algal growth usually swarms with aquatic insects and larvæ.

The bottom of the river also becomes coated with a dark green layer of green algal growth. This layer has a strong tendency to crack and to become turned up at the edges. It is usually seen in this separated form and is typical of dirty condition in a river. In the autumn these separated films of growth frequently become buoyed up with gas bubbles and so float down stream.

Water beetles, water shrimps, larvæ, leeches, etc., are especially plentiful in a reach in this condition.

Grey algal growth is always to be found in such reaches of river, but it is not conspicuous.

The following examples may be cited :—

The river Anker just below the Nuneaton sewage outfall.
The South Delph just below the Lincoln sewage outfall.
The river Chelmer just below the Chelmsford sewage outfall.

Bad.—The water is turbid with finely-divided suspended matter ; it is strongly opalescent ; it emits either a soapy, fœcal or putrid odour which may be smelt some distance from the river.

Fish are absent.

The stones and twigs in the main current are coated with grey algal growth ; those in the pools are covered with either a brown or a black and putrefying deposit.

Water weeds are usually scarce except in small pools protected from the main current, but duck-weed thrives at certain seasons of the year.

Green algae are also to be found in protected pools or sluggish reaches, sometimes in abundance. The variety which forms a layer on muddy bottoms is not only abundant but generally distributed.

Larvae, water shrimps, etc., usually abound, especially if green algal growth is present.

The following examples may be cited :—

The Stock Beck just below the Barnoldswick outfall (1909).
The river Ray below the Swindon outfall (1909–1910).
The river Brent at Perivale (1912).

For convenience of comparison, the above features differentiating the several classes of stream have been set out as far as this can be done in the following table :—

Condition of Water as regards	"Very Clean."	"Clean."	"Fairly Clean."	"Moderate."	"Doubtful."	"Bad."
Suspended matter -	Clear.	Clear.	Fairly clear.	Fairly clear.	Slightly turbid.	Turbid.
Opalescence - -	Bright.	Bright.	Slightly opalescent.	Distinctly opalescent.	Opalescent.	Opalescent.
Smell on being shaken in bottle.	Odourless.	Faint earthy smell.	Pronounced earthy smell.	Earthy wormy smell.	Strong earthy wormy smell.	Soapy, foecal or putrid smell.
Appearance in bulk	Limpid.		Slightly brown and opalescent.	Brown and opalescent.	Black looking.	Brown or black and soapy looking.
Delicate fish - -	May be plentiful.	Scarce.	Probably absent.	Absent.	Absent.	Absent.
Coarse fish - -		Plentiful.	Plentiful.	Present.	Scarce.	Absent.
Stones in shallows -	Clean and bare.	Clean.	Lightly coated with brown fluffy deposit.	Coated with brown or dark green layer.	Coated with brown fluffy deposit.	Coated with grey growth and deposit.
Stones in pools -	Clean and bare.	Covered with fine light brown deposit.	Lightly coated with brown fluffy deposit.	Coated with brown deposit.	Coated with brown fluffy deposit.	Coated with brown or black mud.
Water weeds - -	Scarce.	Plentiful. Fronds clean except in late autumn.	Plentiful. Fronds brown coloured in places.	Abundant and covered with deposit in pools.	Plentiful and covered with fluffy deposit.	Scarce.
Green algae - -	Scarce.	Moderate quantities in shallows.	Plentiful in shallows.	Plentiful.	Abundant.	Abundant in protected pools.
Grey algae - -					Present.	Plentiful.
Insects, larvae, etc -				Plentiful in green algae.	Plentiful in green algae.	Abundant in green algae.

These remarks as to observable condition of river refer more particularly to normal summer conditions, but, subject to the inhibitory action of cold, they may be taken as applying generally to the other seasons of the year also.

All forms of plant life, including green algae, tend to develope increasingly in the spring and to die away or to diminish in the autumn, and in this way they influence according to season every reach of river, but to the ordinary observer the difference in appearance of the river at the several seasons is not so marked as might be imagined. The clearing effect on plant life of heavy floods and also of severe frost is, of course, very noticeable.

The foregoing classification of river reaches as to general observable condition is based upon riverside observations alone. Chemical condition of the water has not been taken into account.

Adhering rigidly to this "field" classification for all the various reaches of rivers which have been under observation for the Commission, we have averaged, for each class of river reach, the figures of chemical analysis yielded by a series of samples drawn therefrom ; no samples being excluded from consideration except a few drawn in times of high flood and containing much suspended matter. There are in all four of these excluded samples, three having been drawn at Alderley Edge and one at Buxton.

The result of this averaging process is shown in the two Tables on pp. 134-5.

In Table I. the figures are averages for samples drawn above the sewage or effluent outfall at each place, while in Table II. they refer to samples drawn below the outfall.

TABLE I.

AVERAGE FIGURES OF ANALYSIS FOR ALL RIVER WATER SAMPLES DRAWN,

(*a*) ABOVE SEWAGE OUTFALL.

		Observed Condition of Stream.	Average Figure of Analysis.	Number of Samples Analysed.	Range of Analysis Figures (lowest to highest).	Percentage of Samples not exceeding the Mean.
Parts per 100,000	Dissolved oxygen taken up in 5 days at 65° F.	Very clean (5)	0·11	12	0·03 — 0·26	40
		Clean (12)	0·21	71	0·05 — 0·50	66
		Fairly clean (7)	0·30	37	0·06 — 0·70	62
		Moderately clean (3)	0·32	14	0·11 — 0·64	57
	Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	Very clean (5)	0·16	12	0·08 — 0·38	70
		Clean (12)	0·27	72	0·12 — 0·70	54
		Fairly clean (7)	0·30	39	0·06 — 0·84	51
		Moderately clean (3)	0·48	14	0·30 — 0·96	64
	Ammoniacal nitrogen	Very clean (5)	0·003	12	0·001— 0·004	90
		Clean (12)	0·024	72	0·002— 0·192	81
		Fairly clean (7)	0·047	39	0·005— 0·294	77
		Moderately clean (3)	0·063	14	0·008— 0·206	71
	Albuminoid nitrogen	Very clean (5)	0·009	12	0·005— 0·015	70
		Clean (12)	0·028	72	0·012— 0·069	60
		Fairly clean (7)	0·035	39	0·009— 0·089	69
		Moderately clean (3)	0·044	14	0·023— 0·074	50
	Nitric nitrogen	Very clean (5)	0·066	12	0·013— 0·128	50
		Clean (12)	0·186	72	0·024— 0·440	57
		Fairly clean (7)	0·208	39	0·030— 0·555	54
		Moderately clean (3)	0·256	14	0·128— 0·400	43
	Suspended solids	Very clean (5)	0·40	5	trace — 1·20	60
		Clean (11)	1·25	42	trace — 4·90	59
		Fairly clean (7)	1·70	21	0·30 — 3·40	52
		Moderately clean (3)	2·38	10	0·70 — 8·10	80
	Chlorine	Very clean (5)	1·16	12	0·55 — 1·71	40
		Clean (12)	2·77	72	1·00 — 8·84	53
		Fairly clean (7)	2·71	39	0·77 — 6·09	59
		Moderately clean (3)	4·35	14	2·20 — 9·18	64
cc. per litre.	Oxygen in solution when drawn.	Very clean (5)	7·45	8	6·68 — 8·76	60
		Clean (10)	6·23	30	3·27 —10·50	67
		Fairly clean (5)	6·63	8	4·00 — 7·98	66
		Moderately clean (2)	5·31	4	4·08 — 5·81	25
	Oxygen in solution when analysed.	Very clean (5)	7·88	12	6·30 — 9·27	50
		Clean (12)	6·53	72	2·61 — 9·18	54
		Fairly clean (7)	6·70	39	0·91 — 9·80	38
		Moderately clean (3)	6·21	14	4·55 — 9·03	50

TABLE II.

AVERAGE FIGURES OF ANALYSIS FOR ALL RIVER WATER SAMPLES DRAWN,

(*b*) BELOW SEWAGE OUTFALL.

—	Observed Condition of Stream.	Average Figure of Analysis.	Number of Samples Analysed.	Range of Analysis Figures (lowest to highest).	Percentage of Samples not exceeding the Mean.
Dissolved oxygen taken up in 5 days at 65° F.	Very clean (2)	0·09	7	0·00 — 0·18	57
	Clean (12)	0·19	87	0·01 — 0·48	61
	Fairly clean (7)	0·26	43	0·05 — 0·59	65
	Moderately clean (11)	0·31	71	0·06 — 0·64	46
	Doubtful (8)	0·48	85	0·16 — 1·27	58
	Bad (5)	0·97	43	0·23 — 2·64	58
Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F.	Very clean (2)	0·22	7	0·12 — 0·35	57
	Clean (11)	0·22	80	0·03 — 0·70	54
	Fairly clean (7)	0·33	45	0·18 — 0·64	56
	Moderately clean (11)	0·31	69	0·14 — 0·63	59
	Doubtful (7)	0·47	82	0·16 — 0·98	52
	Bad (5)	0·68	47	0·15 — 1·55	60
Ammoniacal nitrogen	Very clean (2)	0·005	7	0·003— 0·009	71
	Clean (12)	0·024	87	0·002— 0·216	71
	Fairly clean (7)	0·087	45	0·006— 0·657	73
	Moderately clean (11)	0·071	71	0·005— 0·394	68
	Doubtful (8)	0·252	89	0·029— 0·849	63
	Bad (5)	0·665	47	0·084— 1·650	60
Albuminoid nitrogen	Very clean (2)	0·009	7	0·006— 0·015	42
	Clean (12)	0·025	81	0·007— 0·058	54
	Fairly clean (7)	0·037	42	0·008— 0·097	60
	Moderately clean (11)	0·032	69	0·012— 0·067	55
	Doubtful (7)	0·061	82	0·028— 0·144	59
	Bad (5)	0·096	57	0·030— 0·190	57
Nitric nitrogen	Very clean (2)	0·040	7	0·024— 0·060	71
	Clean (12)	0·205	87	0·020— 0·660	57
	Fairly clean (7)	0·231	45	0·016— 0·490	53
	Moderately clean (11)	0·263	71	0·061— 0·604	45
	Doubtful (8)	0·493	89	0·075— 2·080	60
	Bad (5)	0·395	47	0·016— 1·180	64
Suspended solids	Very clean	—	—	— —	—
	Clean (8)	1·71	32	0·6 — 5·7	53
	Fairly clean (6)	1·14	21	0·3 — 2·7	52
	Moderately clean (10)	1·53	41	0·2 — 3·1	49
	Doubtful (7)	2·15	53	0·6 —18·2	64
	Bad (4)	3·52	37	1·1 —10·7	68
Chlorine	Very clean (2)	0·74	7	0·54 — 1·09	71
	Clean (12)	2·26	87	0·69 —10·70	57
	Fairly clean (7)	3·17	45	1·24 — 8·05	58
	Moderately clean (11)	2·94	71	0·96 — 9·50	69
	Doubtful (8)	5·73	89	1·57 —18·57	67
	Bad (5)	5·68	47	1·21 —10·76	60
Oxygen in solution when drawn.	Very clean (2)	7·05	4	6·80 — 7·43	50
	Clean (8)	6·50	32	3·20 — 7·98	40
	Fairly clean (5)	6·18	21	3·87 — 8·25	42
	Moderately clean (8)	5·57	33	3·10 — 9·24	51
	Doubtful (5)	3·94	36	0·98 — 7·15	41
	Bad (5)	3·63	29	0·50 — 7·14	48
Oxygen in solution when analysed.	Very clean (2)	7·72	7	7·17 — 8·84	71
	Clean (12)	6·71	87	3·35 — 9·58	43
	Fairly clean (7)	5·81	45	0·00 —10·52	53
	Moderately clean (11)	5·81	71	3·52 — 8·58	54
	Doubtful (8)	4·61	89	0·90 — 9 29	55
	Bad (5)	4·27	44	0·00 — 7·00	76

Having selected the absorption of dissolved oxygen in 5 days at 18·3° C. as the test which agrees best with the observed conditions of the stream (*Cf.* Part II., Section I.) it will be well to look more particularly at the average figures of this test. The figures for the other tests can then be dealt with briefly, for much the same considerations apply in each case.

The *average* figures for dissolved oxygen absorption in 5 days now under discussion are as follows:—

Condition of Reach of River.	Dissolved Oxygen taken up from water in 5 days at 18·3° C (65° F.). For River Samples drawn: (*a*) Above Outfall.	For River Samples drawn: (*b*) Below Outfall.
Very clean - -	0·11	0·09
Clean - - -	0·21	0·19
Fairly clean - -	0·30 } 0·31	0·26 } 0·29
Moderately clean -	0·32	0·31
Doubtful - - -	—	0·48
Bad - - -	—	0·97

It should be noted:—

(1) That the above columns of averages given in this subsidiary table result from 469 estimations of dissolved oxygen absorption in 5 days on separate samples of river water.

(2) That each figure in Tables I. and II. is an average of over 35 estimations except in three cases, viz.: "Very clean" above outfall, 11; "very clean" below outfall, 7; and "moderately clean" above outfall, 14.

(3) That the individual figures of the two main Tables are fairly well ranged about the mean figure, rather more being below it than above. The lowest percentage of individual figures below the mean is 46 and the highest 66.

(4) That the range of figures for the individual samples in each class of river is usually of the order of about 1 to 10.

In the Tables the river reaches are given as "above outfall" and "below outfall" for one reason only, namely, as a check on the riverside observations. If the two sets of figures are compared it will be seen that they agree very well, but that in the light of the chemical test the riverside observers have been rather more strict in their judgment of the condition of the reaches below the outfall than of those above the outfall.

For further consideration it will be convenient to merge the two sets of figures together as follows:—

Condition of Reach of River.	Dissolved Oxygen taken up from water in 5 days at 65 ° F.
Very clean - - -	0·10
Clean - - - -	0·20
Fairly clean - - -	0·27 } 0·30
Moderately clean - -	0·31
Doubtful - - - -	0·48
Bad - - - -	0·97

These figures may, we think, be taken as indicating, very broadly, in terms of dissolved oxygen taken up in 5 days, the normal condition of the reach of river from which samples of water have been drawn. If, for instance, samples of water from a given reach persistently yield an average figure of about 0·20, this reach will probably be found "clean" in the sense of the foregoing definitions; if 0·30, it will probably be only "fairly clean"; if 1·0, certainly "bad."

It need hardly be said that it would be unsafe to rely upon the figure of any one test obtained from a single sample; such a procedure would lead to frequent and serious error. The quality of river water, especially of river water subject to admixture of sewage and sewage effluent, necessarily varies from day to day.

The range of figures (for dissolved oxygen absorption in 5 days) between 0·30 and 0·50 is of particular interest. It would seem that at some point between these two figures there exists the dividing line, as indicated by the figures of this test, between satisfactory and unsatisfactory conditions of river; that, theoretically, some figure intermediate between 0·30 and 0·50 would, in fact, be a "limiting figure of impurity for river waters."

Thus, water giving average figures persistently higher than this "limiting figure" would be liable to present unsatisfactory conditions of river, while water giving lower figures would maintain satisfactory conditions of river.

Though there may be difficulty in determining a "limiting figure" by any known test (for it must at once be agreed that, strictly speaking, no definite point or dividing line of this nature could be other than arbitrary and empirical), there are theoretical considerations which tend to show that the adoption of a "limiting figure" may properly be entertained.

The observable condition of a river—upon which alone the present classification of waters is based—implies perception by the observer of objectionable or unobjectionable features.

Conditions potentially objectionable exist in every river and in every reach of river; in reality it is only when such conditions are intensified that their effects are manifested in features which can be recognised as objectionable.

The chief objectionable features which have been taken notice of in these river surveys for the Commission are as follows:—

(1) Smell from the river water when unusually distinct and noticeable.

(2) Exceptional turbidity of the water.

(3) Mud, especially black putrefying mud, in unusual quantity.

(4) Exceptionally thick deposits of solid matter on submerged stones, twigs and plants.

(5) The marked presence of certain grey or green algal growths and the presence in unusual quantity of green algal growths.

(6) Deficiency or absence of fish life.

Just as there is, as regards each of these features, a rough quantity limit, which being exceeded causes it to appear objectionable, so there is or should be a figure for any test which attempts to measure chemically the conditions giving rise to these features.

Of course no test does accurately measure all such conditions; even several tests taken in conjunction with one another may fail in this sense. Nevertheless, a single test may, by itself, afford rough but adequate measure of the quality conditions that are of essential importance.

An objectionable smell (1), for example, does not usually arise from water until the latter is more than half depleted of dissolved oxygen.

A well-oxygenated stream, a sample of which gave in the laboratory the figure of 0·30 for dissolved oxygen absorption in 5 days, would not (being no further polluted) lose oxygen to the extent of becoming half oxygenated in less than 7 to 8 days. In this interval, in a very sluggish stream the water would have travelled something like 10 or 12 miles; if in an ordinarily flowing stream as much as 70 miles. Ten miles of very sluggish river is unusual in this country.

On the other hand, a stream, the water of which gave the figure 0·75 for dissolved oxygen absorption in 5 days,[*] would in two days flow in a very sluggish reach probably become half de-oxygenated. In this interval the water of such a stream would not have flowed more than about 3½ miles. Several examples of sluggish reaches from 3 to 4 miles long could be cited. This latter class of water would, therefore, be liable to give rise to smell in very sluggish reaches. As it contained only 3 c.c. (or less) of oxygen per litre this water would also be inimical to fish life (6).

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[*] We have assumed in this calculation that the water of a stream of such poor quality as this would not be fully oxygenated to start with.

As regards turbidity (2), the water of a perfectly clean river carries with it less than 0·5 part per 100,000 of suspended matter, that of a rather dirty looking stream about 2·0 parts, and of a foul stream 3·0 parts or even more. The appearance of somewhat unusual turbidity, therefore, would probably be represented by the presence of from 2·0 to 3·0 parts of suspended matter.

Our experience leads us to think that such a quantity of suspended matter would usually take up from 0·50 to 0·70 part of dissolved oxygen in 5 days. So that our limiting figure for solids would be in the neighbourhood of 1·5, and this figure would agree fairly well with the limiting figure for dissolved oxygen taken up in 5 days.

As regards algal growth (4 and 5), we are on less secure ground in accepting extra abundance of such growth as evidence of objectionable pollution.

Although we have never seen grey algal growths in any considerable quantity, excepting in water which was organically polluted, we are not prepared to deny that certain inorganic substances may by themselves foster such growth.

In the case of green algae it is well known that ammonia and nitrates do stimulate development.

In certain cases, therefore, there might be found, on the one hand, a good deal of grey, and, on the other, much green growth in waters not otherwise manifesting unsatisfactory conditions, and giving, indeed, figures of analysis well below the "limiting figures."

At Malton, for example, there is a considerable quantity of grey growth (*Cladothrix Dichotoma*) to be seen in the river, though the figures of analysis for the water are usually low. The probable explanation of this is that a good deal of brewery waste, in addition to sewage, is discharged intermittently into the river at Malton.

The experimental channel at Caterham afforded a good instance of a green alga growing luxuriantly in a well-oxidised but highly-nutrient effluent derived from a strongly-ammoniacal sewage.

As showing the disposition of the figures of the individual samples about the "mean figure" in the classes "Moderately clean" (0·31) and "Doubtful" (0·48), the following Table will be of interest. It deals solely with the number of samples comprised in each division of a scale representing dissolved oxygen absorption :—

Dissolved Oxygen taken up from water in 5 days at 65° F.	Number of Samples drawn in River reaches described as being "Moderately Clean."		Number of Samples drawn in River Reaches described as being "Doubtful."	
Parts per 100,000.				
0·05—0·10 - -	7	73% of 85.		
0·11—0·20 - -	17		5	40% of 85.
0·21—0·30 - -	18		14	
0·31—0·40 - -	20		15	
0·41—0·50 - -	15	27% of 85.	22	60% of 85.
0·51—0·60 - -	5		15	
0·61—0·70 - -	3		6	
0·71—0·80 - -	—		1	
0·81—0·90 - -	—		1	
0·91—1·00 - -	—		4	
1·01—2·00 - -	—		2	
Total - -	85		85	

The figures show clearly the different position in the two classes of river reach of the bulk of these samples in reference to a middle term (0·40), arbitrarily taken between 0·30 and 0·50 dissolved oxygen absorption in 5 days.

In studying this Table it should be borne in mind that every sample drawn in these two classes of reach has been placed in order of quality as judged by this test, and it is evident that some chance samples of really bad water are included in the "Doubtful" column, and that a good many samples of clean water are included in both columns.

River-water samples, even from a particular reach, which do not on occasion show similar wide variation in quality are, in our experience, altogether exceptional.

The particular point to be noticed as regards a "mean" figure is that out of 170 samples, all drawn in these two classes of river reach, only 17 gave a "5 days" dissolved oxygen figure above 0·60, and only 37 above 0·50.

Further, it will be seen that 61 of the 170 samples gave figures below 0·30 and that other 72 samples, *i.e.*, nearly half of the 170, gave figures between 0·30 and 0·50.

The lower figure (0·30) of the latter range would, if used as a "limiting figure," err on the side of stringency, and the higher figure (0·50) would certainly be lax.

For practical purposes we adopt the figure 0·40 part per 100,000 as the "limiting figure" for dissolved oxygen taken up from water at 65° F., though the selection of any one figure must needs be arbitrary.

The use of such a figure will be seen below, where it is applied to effluents alone, mixtures of water and effluent, and mixtures of water and sewage liquors.

As regards the other chemical tests, it will be seen from the Tables that :—

(1) The oxygen absorbed from permanganate in 4 hours,

(2) The albuminoid nitrogen ; and

(3) The oxygen in solution when drawn,

give figures which rise fairly regularly as the water gives increasing evidence of unsatisfactory conditions.

If "limiting figures" for these tests were desired, they might be worked out on a similar basis as follows :—

	Parts per 100,000,
Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F. - -	0·40
Albuminoid nitrogen - - - -	0·045
	c.c. per Litre.
Oxygen in solution when drawn - -	4·0

Possible "Limiting figures" for the remaining tests, viz., chlorine nitric nitrogen, suspended solids, etc., need hardly be considered here. In each case the range of the figures is small and their rise, moreover, irregular.

It may now be of some practical interest if we review the results obtained at the various places, in order to see how far the proposed "limiting figure" of 0·4 for river water holds good in the different cases. It has, of course, to be borne in mind that this procedure can only yield approximately correct inferences, seeing that the waters of the various streams were of different degrees of purity ; in other words, the expression "dilution by 'x' volumes" has not always the same meaning. Thus, dilution by 10 volumes of a river water taking up 0·1 part of dissolved oxygen in 5 days is theoretically much the same as dilution by 15 volumes of a water taking up 0·2 part.

The averages of the seven sewage liquors in Tables I. and II., Part II., Section 4, pp. 112A and B, and of the eighteen effluents in Table A, Part II., Section 5 (p. 117), show the following extreme ratios :—

	Sewage Liquors.	Effluents.
Calculated strength - -	about 3·8 : 1	about 4·3 : 1
Dissolved oxygen absorption in 5 days - - -	„ 5·3 : 1	„ 5·7 : 1

These ratio variations are, however, relatively small, as compared with the differing dilutions which the sewage liquors and effluents receive.

Grouped according to dilution, we have :—

SEWAGES AND SEWAGE LIQUORS.

GROUP (*a*).—DILUTIONS FROM 10 TO 1,060.

Barnoldswick - - - - -	10 : 1
Malton - - - - - -	400 : 1
Wye - - - - - - -	660 : 1
St. Neots - - - - - -	960 : 1
Huntingdon - - - - -	960 : 1
Ollerton - - - - - -	1,000 : 1
Pickering - - - - - -	1,060 : 1

EFFLUENTS.

GROUP (*b*).—DILUTIONS FROM 1 : 5.

Swindon	1 : 1
Nuneaton	2 : 1
Buxton	2·5 : 1
Coventry	3 : 1
Berkhamsted	4 : 1
Lincoln	5 : 1

GROUP (*c*).—DILUTIONS FROM 8 TO 15.

Rugby	8 : 1
Alderley Edge	9 : 1
Wilpshire	10 : 1
Cambridge	12 : 1
Kenilworth	15 : 1

GROUP (*d*).—DILUTIONS FROM 26 TO 80.

Halstead	26 : 1
Chelmsford	26 : 1
Hartley Wintney	75 : 1
Consett	80 : 1

GROUP (*e*).—DILUTIONS OF OVER 100.

Stratford-on-Avon	120 : 1
Tiverton	200 : 1
Middleton	1,400 : 1

GROUP (*a*). SEWAGES AND SEWAGE LIQUORS.

	Dilution.	Dissolved oxygen absorption in 5 days at 18° C. by :—		Calculated dissolved oxygen absorption in 5 days by mixture.	Actual dissolved oxygen absorption in 5 days.	Distances below outfall at which samples were drawn (yards).	Observed condition of stream below outfall (*Cf.* Part I. of this Appendix).
		Sewage liquor.	River water above outfall.				
Barnoldswick	10 : 1	14·2 (3)	0·13 (3)	1·41	0·97	200	Bad.
Malton	400 : 1	49·6 (4)	0·13 (6)	0·25	0·25	1,200	Not altogether satisfactory.
Wye	660 : 1	19·5 (5)	0·27 (9)	0·27	0·32	600	Fairly good, excepting for about 200 yards below outfall.
St. Neots	960 : 1	39·2 (5)	0·18 (5)	0·22	0·24	800	Satisfactory, except at outfall.
Huntingdon	960 : 1	34·3 (2)	0·19 (5)	0·24	0·19	700	Satisfactory, excepting close to the outfall.
Ollerton	1,000 : 1					1,000	Satisfactory, except for about 250 yards below outfall.
Pickering	1,060 : 1	21·2 (4)	0·07 (4)	0·09	0·15	600	Satisfactory, except at outfalls.

It will be noted that in every instance comprised in the above Group (*a*), with the exception of Barnoldswick, the calculated five days' dissolved oxygen absorption figure for the stream, after mixture of the sewage liquor with its water, was well under the now proposed limiting figure of 0·4, and that in those six cases the river was either in a satisfactory or fairly satisfactory state, after complete mixture had taken place. At Barnoldswick the mixed sewage liquor and river water gave a figure of 0·97 for dissolved oxygen absorption in 5 days and the beck was in a very bad state for over a mile. The currents are slow to moderate at Wye, St. Neots and Huntingdon, but more or less rapid at Malton, Ollerton, Pickering and Barnoldswick.

GROUP (*b*). EFFLUENTS.

	Dilution.	Dissolved oxygen absorption in 5 days at 18° C. by :—		Calculated dissolved oxygen absorption in 5 days by mixture.	Actual dissolved oxygen absorption in 5 days.	Distances below outfall at which samples were drawn (yards).	Observed condition of stream below outfall (*Cf.* Part I. of this Appendix).
		Effluent.	River water above outfall.				
Swindon	1 : 1	2·72 (11)	0·57 (3)	1·65	1·15 (3)	1,250	Bad.
Nuneaton	2 : 1	2·46 (17)	0·30 (7)	0·84	0·62 (6)	200	Unsatisfactory.
Buxton	2½ : 1	0·93 (16)	0·23 (7)	0·43	0·23 (6)	1,500 and 3,000	Good, excepting for an abundant growth of water plants.
Coventry	3 : 1	1·00 (19)	0·24 (9)	0·43	0·63 (7)	1,000	Unsatisfactory.
Berkhamsted	4 : 1	1·94 (13)	0·33 (6)	0·64	0·36 (3)	500	Not very satisfactory.
Lincoln	5 : 1	1·95 (18)	0·23 (8)	0·42	0·45 (9)	1,400	Unsatisfactory.

The figures in brackets indicate the number of samples examined.

In all the instances comprised in Group (*b*), the dilutions being very low, the calculated 5 days' dissolved oxygen absorption figure of the admixed water and effluent always exceeded the now proposed limiting figure of 0·40, and, excepting in the case of Buxton, the streams were in an unsatisfactory condition. At Buxton the current is very rapid and the stream from its source onwards is continually receiving accessions of fresh water, so that within a mile from the outfall the dilution given to the effluent is probably about 5 or 6 times the original dilution. At all the other places the current is slow to sluggish, and hence suspended solids readily settle in the bed of the stream and thus accentuate the polluting effect of the discharge.

The actual figure for dissolved oxygen absorption in 5 days, given by the samples of water drawn at points sufficiently far below the outfall to allow of good mixture having taken place, was also over 0·4, excepting in the cases of Buxton and Berkhamsted.

It will be noted, in this and the following three tables, that the number of effluents examined was much greater than that of the river waters. The figures, therefore, are not strictly comparable, for, while the effluent figures may be generally accepted as fairly average ones, those for the river waters above and below the outfall are in a good many cases deduced from only a few analyses. Still, we are satisfied from our observations that these figures for river water may be taken as fairly representative.

GROUP (*c*). EFFLUENTS.

	Dilution.	Dissolved oxygen absorption in 5 days at 18° C. by :—		Calculated dissolved oxygen absorption in 5 days by mixture.	Actual dissolved oxygen absorption in 5 days.	Distances below outfall at which samples were drawn (yards).	Observed condition of stream below outfall (*Cf.* Part I. of this Appendix).
		Effluent.	River water above outfall.				
Rugby - -	8 : 1	2·09 (15)	0·25 (8)	0·45	0·34 (7)	800 and 400	Satisfactory, excepting in very sluggish reaches below the outfalls.
Alderley Edge -	9 : 1	1·28 (15)	0·28 (5)	0·38	0·52 (5)	1,700	Not altogether satisfactory. The water above outfall is very impure in times of storm.
Wilpshire - -	10 : 1	1·16 (11)	0·18 (4)	0·27	0·24 (4)	1,500 and 800	Satisfactory, except for grey algal growth just below outfall. The stream receives drainage from the streets.
Cambridge - -	12 : 1	1·15 (12)	0·18 (3)	0·25	0·33 (3)	800	Satisfactory.
Kenilworth - -	15 : 1	1·33 (14)	0·34 (7)	0·40	0·29 (6)	1,300	Fairly satisfactory. The stream is polluted above the outfall.

In Group (*c*), where the dilutions are still rather small, the calculated figure for dissolved oxygen absorption by the admixed water and effluent was well below 0·4 in two cases and about 0·4 in the other three; the actual figures agreed only fairly well with the calculated figures. In the two cases where the streams were noted as being in an unsatisfactory condition (Wilpshire and Alderley Edge), both receive drainage from the streets, while in the second case the water above the outfall is very impure in times of storm and contains then much suspended matter.

Excepting at Alderley Edge, where the stream is fairly rapid, the current in all the other cases of Group (*c*) is either slow or sluggish.

GROUP (*d*). EFFLUENTS.

	Dilution.	Dissolved oxygen absorption in 5 days at 18° C. by :—		Calculated dissolved oxygen absorption in 5 days by mixture.	Actual dissolved oxygen absorption in 5 days.	Distances below outfall at which samples were drawn (yards).	Observed condition of stream below outfall (*Cf.* Part I. of this Appendix).
		Effluent.	River water above outfall.				
Halstead - -	26 : 1	0·79 (7)	0·18 (2)	0·20	0·44 (2)	600	Unsatisfactory, because of discharge of night sewage.
Chelmsford - -	26 : 1	1·74 (18)	0·23 (10)	0·29	0·39 (8)	1,400	Not satisfactory.
Hartley Wintney	75 : 1	1·68 (13)	0·14 (4)	0·16	0·17 (4)	200	Satisfactory.
Consett - -	80 : 1	0·87 (9)	0·05 (2)	0·06	0·07 (2)	400	Satisfactory.

In Group (*d*), with fairly large dilutions, the calculated figure for dissolved oxygen absorption by admixed water and effluent was always well under 0·4, but the actual figure was only well under it in two cases (Hartley Wintney and Consett), where the streams were in a satisfactory condition; the respective currents were moderately rapid and rapid. At Chelmsford, the flow is sluggish and hence the deposition of suspended matter is favoured. At Halstead, where the current below the outfall is very sluggish, night sewage and storm sewage were usually sent direct to the river; our samples having been drawn in the day time, the figures of analysis cannot be taken as representing the quality of the river water below outfall throughout the 24 hours of the day.

GROUP (*e*). EFFLUENTS.

	Dilution.	Dissolved oxygen absorption in 5 days at 18° C. by :—		Calculated dissolved oxygen absorption in 5 days by mixture.	Actual dissolved oxygen absorption in 5 days.	Distances below outfall at which samples were drawn (yards).	Observed condition of stream below outfall (*Cf.* Part I. of this Appendix).
		Effluent.	River water above outfall.				
Stratford-on-Avon	120 : 1	0·80 (11)	0·26 (5)	0·27	0·24 (5)	100,400 and 5,000	Satisfactory.
Middleton - -	200 : 1	3·94 (11)	0·14 (3)	0·16	0·11 (3)	300	Satisfactory (except near point of discharge).
Tiverton - -	1,400 : 1	4·57 (11)	0·18 (3)	0·18	0·21 (2)	1,000	Satisfactory (except at point of discharge).

In Group (*e*), with large and very large dilutions, the calculated figure for admixed effluent and water was in all three cases well under 0·4, as was also the observed figure. The streams were in a satisfactory state, excepting near the points of discharge at Middleton and Tiverton. The current at Stratford is rather sluggish, but it is fairly rapid and rapid, respectively, at the other two places.

On a general review of these figures for effluents, we find that in fourteen of the eighteen streams under discussion the observed state of the stream bears out in one way or another the proposed "limiting figure" of 0·4 for the mixture of water and effluent. In three of the remaining four cases (Berkhamsted, Wilpshire and Halstead), where the observed conditions of the stream and the amount of oxygen taken up by its water in 5 days do not correspond to expectation, there are complicating factors which, when taken into consideration, account for the discrepancies. In the last case (Chelmsford), where according to calculation the mixed effluent and water should give a figure well under 0·4, the actual figure is almost exactly 0·4, which corresponds fairly well with the observed doubtful condition of the stream.

Twelve of the above eighteen streams have in dry weather slow to sluggish currents, so that suspended solids from the effluent readily settle and give rise to mud, which is persistently deoxygenating the water above it. It seems hardly necessary to add that if two streams giving equal dilution to effluents of similar quality have the one a rapid and the other a sluggish current, the first may be expected to deal satisfactorily with more polluting matter than the second, seeing (1) that it can reoxygenate itself more rapidly; and (2) that the suspended solids from the effluent are dispersed over a wider area.

SECTION 7.

ON THE COMPOSITION OF VARIOUS FRESH WATER PLANTS AND ALGÆ, TAKEN FROM STREAMS RECEIVING SEWAGE EFFLUENTS.

Fresh water plants and algæ are such important factors in respect to the purification of the waters of polluted streams, that it was thought advisable to examine chemically some of the more commonly occurring varieties. Sixteen samples (13 plants, 2 algæ, and 1 moss) were therefore collected at different times from various streams. Their figures of analysis are given in Table I., which also includes a further alga, *Prasiola crispa*, taken from a primary contact bed.

Before proceeding to discuss the analytical results, it may be well to state shortly what we understand the terms "fresh water plant" and "fresh water alga" to mean, and to give a brief account of the process followed in preparing the samples for analysis and of the subsequent chemical methods.

By "fresh water plants" we mean the higher forms of plant life, having their habitat in fresh water, either floating or attached by roots to the bed of the stream. By "algæ" we mean the lower forms of plant life—cellular, flowerless, mainly rootless, and deriving their sustenance from the water.

The following is the list of samples examined:—

FRESH WATER PLANTS.

		Sample taken from:—
Buxton, River Wye.	*Ranunculus aquatilis* (Water crowfoot).	200 yards below outfall, December, 1910.
Berkhamsted.	,, ,,	Clean water stream, January, 1911.
Coventry, River Avon.	,, ,,	Above outfall near Ryton Bridge, January, 1911.
Rugby, ,, ,,	,, ,,	Below effluent outfall, June, 1911.
,, ,, ,,	Grass admixed with above sample of *Ranunculus*, June, 1911.	
,, ,, ,,	*Nuphar luteum* (Yellow water lily).	Below effluent outfall, June, 1911.
Coventry.	*Nasturtium officinale* (Water cress).	Shallow ditch bordering Rock Cottage garden, February, 1911.
Luton.	,, ,,	Clean water stream March, 1911.
Ollerton, River Maun.	*Myriophyllum spicatum* (Water milfoil).	10 yards below sewage outfall, December, 1910.
Wye, River Stour.	*Callitriche verna* (Water starwort).	400 to 500 yards below sewage outfall, January, 1911.
Clifton (Notts), River Trent.	*Ceratophyllum demersum* (Hornwort).	At Marshall's Parlour, January, 1911.
Ollerton, River Maun.	*Elodea Canadensis* (American water weed).	10 yards below sewer outfall, December, 1910.
Barnsley, River Dearne.	*Potamogeton pectinatus* (Fennel-leaved pond weed).	Below effluent outfalls, July, 1911.

ALGÆ.

Harrow, Sewage Works.	*Prasiola crispa.*	Primary contact bed, October, 1912.
Chelmsford, River Chelmer.	"Flannel" weed (Sp. ?).	Below effluent outfall, November, 1910.
Rugby, River Avon.	,, ,, (Sp. ?).	Below effluent outfall, July, 1911.

MOSS.

Rugby, River Avon.	*Fontinalis antipyretica.*	Below effluent outfall, January, 1911.

CLEANSING THE SAMPLE.

The plant or alga, as received, was always infested more or less with animal life (larvæ, worms, fresh-water shrimps, etc.), indeed, was sometimes swarming with this, while it might also contain vegetable matter of other kinds, either alive or dead, together with mud and sand. It was therefore necessary to cleanse the sample in the first instance. This was done by washing it as often as was found needful in large quantities of water, contained in crocks or basins, and after the bulk of the loose matter had been separated in this way, the remaining larvæ, etc., were picked out from small portions of the sample at a time, the latter being held by forceps in the water. The process was repeated with fresh water as often as required. It was frequently very tedious, especially with the more filamentous algæ, and much time had to be spent in getting what, after all, was often but a small sample. In this way the samples were obtained practically, though not absolutely, clean.

After being cleansed, the sample was allowed to drain on filter paper (it was not pressed, in order that the juices might be retained), to separate adherent water, and was then dried in a small basin on the water-bath. The dried residue, powdered up, was taken for analysis. The samples, dried in this way, were found still to contain small quantities of moisture (2·5 to 14·2 per cent.); this moisture was estimated and allowed for in calculating the results of analysis.

ESTIMATION OF MOISTURE, MATTER VOLATILE ON IGNITION, AND IRON.

A small weighed portion of the sample (about 0·5 to 1·0 gramme, except when the total amount available was very small) was dried at 105° C. to constant weight, for the *Moisture;* it was then heated and ignited to constant weight, for the *Volatile matter.*

In order to make the sample go as far as possible, the residue from this ignition was taken for estimation of the iron. It was warmed with a little hydrochloric and, if necessary, a few drops of nitric acid, the solution diluted and filtered, and the iron in the filtrate thrown down by ammonia as ferric hydroxide. After filtering off and washing the latter, it was dissolved on the filter by dilute sulphuric acid (1 in 6 by volume), the solution reduced by zinc, and the iron titrated with (approximately) $\frac{N}{8}$ permanganate (for details, *cf.* paper on *River Muds* in this Appendix, p. 147). "Blank" determinations with zinc and acid alone were done from time to time, the figure obtained for the blank being deducted from that of the estimation proper. Those blanks were relatively higher than was desirable, averaging 12 per cent. of the total figure in seven estimations, while in one case, with the low figure of 0·12 per cent. *Fe*, the blank which had been deducted was equivalent to 0·08 per cent.

ESTIMATION OF MINERAL MATTER INSOLUBLE IN ACID, AND OF SULPHUR AND PHOSPHORUS.

To about 1 gramme* of the dried and powdered plant or alga, contained in a small porcelain basin, a little concentrated nitric acid was cautiously added, and, after warming on the water bath, some concentrated hydrochloric acid. Warming was continued until everything possible was dissolved, small quantities of the acids being added from time to time, as required. After that, the liquid was evaporated to dryness, and the residue moistened with a few drops of hydrochloric acid and allowed to stand for a short time. Excess of water, together with a little hydrochloric acid, was then added, the whole warmed and filtered, and the residue on the filter washed, dried and ignited; this gave *Insoluble mineral matter.*

In the filtrate the sulphuric acid was then estimated gravimetrically as sulphate of barium. This gave *Total Sulphur.*

The filtrate from the barium sulphate, after the addition of a little nitric acid, was in its turn evaporated to dryness, to expel hydrochloric acid, the residue taken up with a little more nitric acid and water, and the phosphoric acid thrown down by molybdate and finally estimated as magnesium pyrophosphate. This gave *Total Phosphorus.*†

The results of the analyses are given in Table I.

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* We had often to work with much less than 1 gramme (as little as 0·35 gramme in one instance), but it is not desirable to do so.

† It should be added, however, that the figures for phosphorus in Table I. may possibly be a little lower than the reality, as the nitric acid solution always contained a certain amount of organic matter, which is known to prevent to some extent the precipitation of phosphoric acid by molybdate of ammonia. The results would, no doubt, have been rather more accurate had this organic matter been destroyed before the precipitation.

TABLE I.—WATER PLANTS. ANALYSES OF SEVERAL VARIETIES OF FRESH WATER PLANTS AND ALGÆ.

All figures expressed as parts "per cent."

Number of sample.	Place: Nature of sample.	Date of taking sample.	Analysis begun.	Calculated on washed sample, dried on water bath.			Calculated on dry sample (dried to constant weight at 105° C.).							Remarks.
				Moisture.	Volatile matter.	Non-volatile matter (Ash).	Volatile matter.	Non-volatile matter (Ash).	Matter insoluble in hydrochloric acid (after ignition).	Total Iron. (*Fe*)	Total sulphur (*S*).	Total phosphorus (*P*).	Total nitrogen (by Kjeldahl) (*N*).	
	WATER PLANTS.													
124 K	BUXTON. River Wye. "*Ranunculus aquatilis*" (water crowfoot). Taken about 200 yards below effluent outfall.	Dec. 6, 1910	Dec. 13, 1910	5·3	68·6	26·1	72·6	27·4	11·68	1·24	0·37	0·34	3·62	River in good condition.
127 K	BERKHAMSTED. "*Ranunculus aquatilis*" from clean water stream near canal.	Jan. 9, 1911	Jan. 11, 1911	5·0	77·4	18·6	80·4	19·6	3·56	0·00	0·40	0·80	4·77 4·93	
B	COVENTRY. River Avon "*Ranunculus aquatilis*," taken near Ryton Bridge, *i.e.*, above effluent outfall.	Jan. 23, 1911	Feb. 2, 1911	6·2	71·6	22·2	76·3	23·7	2·39	0·12	0·94	0·59	3·84 3·69	River in good condition.
	RUGBY. River Avon. "*Ranunculus aquatilis.*" Taken below effluent outfall.	June 20, 1911	June 27, 1911	13·2	—	—	86·8	13·2	2·06	—	0·33	0·47	3·89 4·44	River in very fair condition.
	RUGBY. Grass which was mixed with above sample of *Ranunculus.*	June 20, 1911	—	7·0	—	—	—	—	—	—	—	—	1·60	
	RUGBY. River Avon. *Nuphar luteum.* Water-lily taken below effluent outfall.	June , 1911	July 6, 1911	12·2	78·2	9·6	89·1	10·9	0·59	—	0·29	0·47	5·42 5·48	River in very fair condition.
C	COVENTRY. River Avon. *Nasturtium Officinale* (Water-cress), from a shallow ditch bordering Rock Cottage Garden.	—	Feb, 1911	14·2	71·6	14·6	83·0	17·0	7.08	0·80	0·97	0·51	5·59 5·90	

TABLE I.—*continued.*

Number of sample.	Place: Nature of sample.	Date of taking sample.	Analysis begun.	Calculated on washed sample dried on water bath.			Calculated on *dry* sample (dried to constant weight at 105° C.).							Remarks.
				Moisture.	Volatile matter.	Non-volatile matter (Ash).	Volatile matter.	Non-volatile matter (Ash).	Matter insoluble in hydrochloric acid (after ignition).	Total iron (*Fe*).	Total sulphur (*S*).	Total phosphorus (*P*).	Total nitrogen (by Kjeldahl) (*N*).	
	WATER PLANTS—contd. LUTON. Water-cress from a clean water stream.	—	Mar. 27, 1911	12·2	70·2	17·6	80·0	20·0	0·49	0·00	1·07	1·01	6·51 6·43	
125 K (*b*)	OLLERTON. River Maun. "*Myriophyllum spicatum*" (Water Milfoil). Taken about 10 yards below sewage outfall.	Dec. 6, 1910	Dec. 13, 1910	4·0	82·8	13·2	86·2	13·8	7·62	0·38	0·32	0·44	5·34	River in good condition.
126 K	WYE (Kent). River Stour. "*Callitriche verna*" (Water Starwort). Taken from ditch mouth at river, about 400–500 yards below sewage outfall.	Jan. 6, 1911	Jan. 10, 1911	6·1	73·4	20·5	78·2	21·8	1·46	3·25	0·46	0·38	4·50 4·42	River in fair condition.
K	CLIFTON (Nottingham). River Trent. "*Ceratophyllum demersum*" (Hornwort), from near Marshall's parlour.	—	Jan. 5, 1911	2·4	83·9	13·7	85·9	14·1	1·41	0·00	0·32	0·54	3·13 3·22	River in fair condition.
125 K(*a*)	OLLERTON. River Maun. "*Elodea Canadensis*" (American Water-Weed), from 10 yards below sewage outfall.	Dec. 6, 1910	Dec. 13, 1910	17·5	—	—	—	—	8·74	0·59	0·54	0·93	3·96	
	BARNSLEY (Lancs). "*Potamogeton pectinatus*" (Fennel - leaved Pond weed), taken below effluent outfall.	—	July, 1911	10·0	—	—	85·1	14·9	4·41	—	0·39	0·31	3·72 3·70	

TABLE I.—*continued.*

Number of sample.	Place: Nature of sample.	Date of taking sample.	Analysis begun.	Calculated on washed sample dried on water bath.			Calculated on *dry* sample (dried to constant weight at 105° C.).							Remarks.
				Moisture.	Volatile matter.	Non-volatile matter (Ash).	Volatile matter.	Non-volatile matter (Ash).	Matter insoluble in hydrochloric acid (after ignition).	Total iron (*Fe*).	Total sulphur (*S*).	Total phosphorus (*P*).	Total nitrogen (by Kjeldahl) (*N*).	
	ALGÆ.													
	HARROW. "*Prasiola crispa*," from contact bed.	—	Oct. 25, 1912	—	—	—	—	—	—	—	0·43	0·16	6·67 6·91	
191 K	CHELMSFORD. River Chelmer. "*Chaetomorpha sutoria** (Flannel weed), from 10 yards above Stoneham's Weir.	Nov. 21, 1910	Nov. 23, 1910	12·3	65·3	22·4	74.5	25·5	1·44	0·89	1·61	0·79	5·05	River in fair condition.
	RUGBY. River Avon. Flannel weed from Newbold Weir, below Rugby effluent outfall.	—	July 6, 1911	6·9	82·5	10·6	88·7	11·3	5·73	—	1·33	0·17	4·98 4·75	River in very fair condition.
	MOSS.													
A	RUGBY. River Avon. A moss, "*Fontinalis antipyretica*," growing on brickwork just above Little Lawford Mill.	Jan. 23, 1911	Feb. 2, 1911	8·6	77·6	13·8	75·0	15·0	1·17	0·36	0·40	0·72	3·72	

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* This alga as received was full of (dead) water shrimps, which were, of course, separated. The shrimps, after being dried, were found to contain 0·49 per cent. of Sulphur and 1·01 per cent. of Phosphorus.

The foregoing table shews that, in eleven of the twelve water plants examined, the percentage of matter volatile on ignition (calculated on the *dry* sample), which may be taken approximately as organic matter, varied from 72·6 to 89·1, the average being 82 per cent. Apart, therefore, from the water that they contained, four-fifths of the dry matter of the water plants was organic. Further, this organic matter was largely nitrogenous, the percentage of nitrogen in the twelve (dry) samples varying from 3·18 to 6·47, and averaging 4·56.

That this remarkably high nitrogen content is the striking characteristic of these fresh water plants is at once seen by comparing their nitrogen figures with those of the typical land plants cited in Table II. (below).

Part (A) of this Table has been kindly supplied to us by Dr. E. J. Russell, Rothamsted, and Part (B) by Dr. Alexander Lauder, East of Scotland College of Agriculture, Edinburgh. Writing on the subject, Dr. Russell says:

> "The percentage (of nitrogen), however, is by no means constant, but varies considerably with the method of treatment and the manuring. The general rule is that the higher the amount of nitrogen compounds in the soil, the larger the percentage of nitrogen in the plant; and, further, plants supplied with ammonium sulphate contain higher percentages of nitrogen than those supplied with nitrate, unless the conditions have been favourable to a rapid transformation of the ammonia."

TABLE II. SHOWING THE PERCENTAGES OF NITROGEN IN THE DRY MATTER OF SOME LAND PLANTS.

(A.)	Nitrogen, per cent.
Clovers	3·3 to 4·0
Grasses	1·8 to 3·4
Buckwheat	1·2 to 3·0
Rye (straw)	0·5
,, (grain)	1·2
Wheat (straw)	0·3
,, (grain)	1·9
Mustard	2·3 to 4·4

(B.) *INDIVIDUAL CLOVERS AND GRASSES.

Clovers.	Nitrogen, per cent.
Red clover hay	2·77
Lucerne before flowering	3·06
Lucerne in flower	2·72
Sainfoin before flowering	2·76
Sainfoin in flower	2·52
Grasses.	
Bent or Creeping Grass (*Agrostis alba*)	1·31
Meadow Foxtail (*Alopecurus pratensis*)	1·77
Sweet Vernal (*Anthoxanthum odoratum*)	1·39
Yellow Oat-Grass (*Avena flavescens*)	1·03
Crested Dogstail (*Cynosurus cristatus*)	1·51
Rough Cocksfoot (*Dactylis glomerata*)	1·17
Hard Fescue (*Festuca durinscula*)	0·99
Tall Fescue (*Festuca elatior*)	1·17
Meadow Fescue (*Festuca pratensis*)	1·24
Sheep's Fescue (*Festuca ovina*)	1·47
Italian Rye-grass (*Lolium italicum*)	1·15
Timothy (*Phleum pratense*)	1·45
Smooth-stalked Meadow Grass (*Poa pratensis*)	1·29
Rough-stalked Meadow Grass (*Poa trivialis*)	0·92

Reverting to the fresh-water plants and algæ:

The highest nitrogen content (6·47 per cent. on the *dry* plant) is shown by the sample of water-cress obtained from a clean water stream at Luton; but it has to be remembered that this water had an abundance of nitrate, although it contained only the traces of ammonia and carbonaceous matter that are to be found in good drinking waters.

Of the four samples of ranunculus examined, that from the clean water stream at Berkhamsted (no doubt also rich in nitrate) again showed the highest percentage of nitrogen (4·85). It will be noticed that the range in percentage of nitrogen in these four samples of ranunculus was not very great, viz., 3·62 to 4·83. Without having data on the subject, we should expect the same thing to hold good for aquatic as for land plants, viz., that both the actual yield of plant and (within limits) its composition would vary with (*a*) the amount of food constituents supplied to it, and (*b*) the relative proportions of those constituents.

The amounts of iron found in these various water plants were very different, varying from practically none † to 3·25 (this in a sample of starwort from the River Stour, Wye, Kent). The (dry) Coventry water-cress contained 0·80 per cent. of iron, while that from Luton contained none. It would be interesting to examine for iron the waters in which the two samples of water-cress grew. We can only say that, from observation, the soil and sub-soil in the former case are reddish-brown with oxide of iron, while in the latter the formation is chalk.

The percentage of sulphur in the dry plants ranged from 0·29 to 1·07, and averaged 0·53, while the percentage of phosphorus ranged from 0·31 to 1·01, and averaged 0·57. With a few exceptions, the sulphur and phosphorus were present in somewhat similar amounts in the same plant. It is noteworthy that the Luton water-cress gave the highest figures for both sulphur and phosphorus, as well as for nitrogen.

The two samples of river algæ examined, from Chelmsford and Rugby, were also rich in nitrogen, each containing about 5 per cent.; but the highest nitrogen content of all the samples given in Table I. was shown by the alga, *Prasiola crispa* (6·79 per cent.), which was found growing luxuriantly on a primary contact bed at Harrow. The moss, *Fontinalis antipyretica*, from Little Lawford Mill, Rugby, contained 3·72 per cent. of nitrogen.

Since such aquatic plants and algæ grow in great abundance in all streams containing nitrogen compounds in solution, and therefore in all streams receiving sewage effluents (unless the stream be made very foul), they may be looked upon not merely as important factors in the purification of the water, but also as intermediaries for collecting and transforming ammonia and nitrate, which would otherwise be carried out to sea. If, instead of allowing them to decay and produce a deposit of mud on the river bed, they were more habitually collected and made use of as nitrogenous manure (*e.g.*, by making them into a compost with soil), much valuable material would be saved.‡ It seems hardly likely that harm would be done, in the way of encouraging growth of weeds, by distributing such a compost upon land, for aquatic vegetation could not flourish on dry soil. Possibly, too, it might be worth while to utilise the surfaces of contact beds for growing crops of *Prasiola crispa* or other algæ, to recover for manure some of the nitrogen which would otherwise be discharged in the effluent.

Reference may be made, in conclusion, to Section I. Addendum I., p. 85, of this Appendix, where details are given of some laboratory experiments showing the absorption, by water plants and algæ, of ammonia and nitrate from water to which chloride of ammonium and nitrate of potassium had been added in known quantities.

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* The figures in Part (B) were collected from a variety of sources, mostly from analyses by Dr. Voelcker.

† Iron was taken as being practically absent if the ash was white or nearly so.

‡ The good manurial effect of the deposit of mud left on meadows by the overflow of a stream in flood is well known.

SECTION 8.

ON THE COMPOSITION AND PROPERTIES OF SOME MUDS TAKEN FROM THE BEDS OF STREAMS RECEIVING SEWAGE EFFLUENTS.

In order to gain information with regard to the deoxygenating qualities of the muds deposited in the beds of streams receiving more or less purified sewage effluents, eleven typical samples of mud were drawn, nearly all of them made up of a number of sub-samples. The sources of these samples, together with their figures of analysis, are to be found in the appended Tables I. and II.

The muds were analysed as received, excepting in the case of No. 128 K, which was swarming with small pink worms. This sample was therefore sieved into a vessel containing water through a fine zinc sieve, the holes of which were about 0·5 mm. or less in diameter, the bottom of the sieve being dipped into the water. The sieved mud was then allowed to settle and the supernatant water drained off.

The *methods of analysis* followed may be given shortly:—

Three fair sub-samples of the mud to be analysed—(*a*), (*b*) and (*c*)—each about 10 grammes, were weighed out in small porcelain basins.

(*a*) Estimation of Moisture and of Matter Volatile on Ignition.

This portion of the mud was evaporated on the water bath and the residue then dried in the hot-air oven at 105° C. to constant weight; the dried residue was then ignited and weighed in its turn, until constant.

(*b*) Estimation of Sulphur, Present in other Form than Sulphide, and of Iron Soluble in Cold Dilute Hydrochloric Acid.

The weighed portion of mud was washed out of the basin into a small conical flask by means of a pipette containing dilute acid. This acid consisted of 5 per cent. by volume of hydrochloric acid and 95 per cent. of water, the total quantity used in each estimation being 100 cc. Carbon dioxide was then bubbled through the muddy liquid in the flask, until no more sulphuretted hydrogen came off with it. The mixture was then filtered, the residue on the filter paper washed with warm water, and the (cooled) filtrate made up to 200 cc.

(1) 100 cc. of this were taken for the estimation of the iron. After oxidizing with nitric acid, the ferric hydroxide was thrown down by ammonia, filtered, washed thoroughly, and redissolved on the filter by a mixture containing 20 cc. sulphuric acid and 100 cc. water. The ferric sulphate in this solution was then reduced, by means of zinc, in a conical flask closed by a rubber stopper with Bunsen valve attached. When it was judged that complete reduction would have taken place, a drop of the solution was tested for this by potassic thiocyanate. The solution was finally titrated for iron with $\frac{N}{8}$ or $\frac{N}{80}$ permanganate (as the case might be), a "blank" titration being also done occasionally with zinc and acid alone. Excepting in the case of No. 308, the "blanks" were practically negligible; at the same time it is difficult to get a sharp end-point in this titration, when the iron has been reduced by zinc.

(2) In the second 100 cc., the sulphur present as sulphate was determined gravimetrically in the usual way, as sulphate of barium.

(*c*) Estimation of insoluble Mineral Matter, Total Sulphur and Total Phosphorus.

The weighed-out mud was dried on the waterbath, then cautiously treated with a small quantity of concentrated nitric acid, and the mixture evaporated to dryness. This was repeated a second time, after which two evaporations were done with a little hydrochloric acid. The residue was now moistened with a few drops of hydrochloric acid, about 20 cc. of water were added, and the whole was warmed and filtered and the precipitate washed. The precipitate, after drying, was ignited and weighed; this gave the *insoluble matter*.

The sulphuric acid in the filtrate was estimated gravimetrically as barium sulphate, which gave the *total sulphur*.

The filtrate and washings from the sulphate of baryta were evaporated to dryness, to get rid of hydrochloric acid, and the phosphoric acid was then thrown down by molybdate in nitric acid solution, and finally weighed as magnesium pyrophosphate. This gave the *total phosphorus*.

(*d*) Oxygen Absorbed from $\frac{N}{8}$ Permanganate in 4 Hours at 27° C. (80° F.).

For this estimation, about 0·25 gramme of a presumably bad river mud is a convenient quantity to take, *i.e.*, about 25 grammes of the mud are made up to 500 cc. with water, and 5 cc. of this mixture are taken. In the case of less impure muds, it is advisable to take somewhat larger amounts.

(*e*) Nitrogen.

This was determined by the Kjeldahl method, about 10 grammes of mud being, as a rule, taken for each estimation.

(*f*) Dissolved Oxygen Absorption at 18° C. (65° F.) in 24 Hours, 48 Hours and 5 Days.

The quantity of river mud most suitable for these estimations must necessarily vary. For muds which it is anticipated will take up much oxygen (like, *e.g.*, No. 192 K), about 1 gramme of wet mud (= 0·2 to 0·25 of dry matter) per litre of water is sufficient; while, for muds of less oxygen absorbing power (*e.g.*, No. 123 K), 4 to 5 grammes of wet mud per litre are not too much.

Our usual method (*i.e.*, Winkler's process, as modified by Rideal and Stewart) was followed here, bottles of about 350 to 360 cc. capacity being used, but certain precautions were found to be necessary, viz.:—

For the *initial* determination of oxygen in solution, it is better to take the tap water alone (previously warmed as usual to 18° C. and shaken), and not the water to which the mud has been added. The oxygen in such a mixture is certain to come out too low, because of the rapid oxidation of the iron sulphide of the mud. The mud particles too, exercise a disturbing effect upon the iodine eventually liberated for titration with thiosulphate, this tending to make the result too high.

For the *final* determination: Shortly before the actual determination of the oxygen remaining in solution at the end of the 24 hours, etc., the bottle is rotated once or twice, to ensure the liquid being made homogeneous, and the solid particles are now allowed to settle for, say, half an hour. The greater portion of the liquid is then siphoned quietly through a narrow-bore siphon into a smaller bottle of about 280 cc. capacity, which has been previously filled with carbon dioxide*, the first 25 cc. of the siphoned liquid (in our experiments) being rejected, and a little being also allowed to overflow at the end. The bottle is then stoppered and the determination of the oxygen remaining in solution made in the usual way.

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* It takes a good deal longer to push out all the air from even a small bottle by carbonic acid from a Kipp apparatus than might be supposed.

TABLE II.—Analysis of River Muds.

All figures in this Table indicate parts per cent. of the *Volatile Matter* of the dried mud (*i.e.*, matter volatile on ignition).

Number of sample.	Place.	Date when drawn.	Date when analysed.	Total phosphorus. (*P*)	Total iron (*Fe*)	Total sulphur. (*S*)	Sulphur present in some other form than sulphide.	Sulphur required to form sulphide with the iron present.	Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.).	Nitrogen. (*N*)	Dissolved oxygen taken up from excess of water:— at 18° C. (65° F.) in 24 hours.	at 18° C. (65° F.) in 48 hours.	at 18° C. (65° F.) in 5 days.	At air temperature in 156 to 225 days.	Dissolved oxygen taken up from still water at 18° C. in Adeney apparatus in 650 days.
	R. Anker.														
304	*Nuneaton.* Taken below outfall (average of 12 samples).	Oct. 12, 1910	Oct. 20, 1910	1·70	8·10	6·21	Trace	4·63	29·85	4·44	—	—	3·25	12·5 ap.† (225)	20·5
305	*Nuneaton.* From above outfall (chance sample).	Oct. 12, 1910	Dec. 16, 1910	—	—	6·66	—	—	64·30	4·94	12·23	14·14 (3)*	15·95	—	—
	R. Avon.														
306	*Coventry.* From above outfall at Ryton Bridge (average of 12 samples).	Oct. 13, 1910	Oct. 18, 1910	1·11	8·81	4·62	1·11	5·05	32·42	4·11	—	—	1·61 (6)	15·4 ap. (169)	14·4
307	*Coventry.* From above outfall at Ryton Bridge (average of 3 samples).	Oct. 12, 1910	Dec. 16, 1910	—	—	5·66	—	—	46·15	4·34	8·79	9·99	12·15	—	—
309	*Coventry.* From below outfall at Rock Spinney (average of 3 samples).	Oct. 13, 1910	Oct. 19, 1910	1·80	14·31	9·15	0·47	8·18	41·21	5·09	5·55	7·60	11·02 (6)	23·0 (166)	24·8
308	*Coventry.* From below outfall at Bubbenhall up to Rock Spinney (average of 15 samples).	Oct. 13, 1910	Oct. 17, 1910	2·11	10·88	11·69	Trace	5·07	42·98	4·60	—	—	8·67 ap.	28·2 + *x* ‡ (189)	32·4
x	*Coventry.* An average sample from below outfall near the further end of Rock Spinney (towards Bubbenhall Mill).	April 25, 1911	April 27, 1911	1·71	5·99	4·23	0·31	3·42	37·47	4·65	3·72	4·23	8·19	—	—
	R. Chelmer.														
192 K	*Chelmsford.* From five yards below effluent outfall (an average sample).	Nov. 21, 1910	Nov. 28, 1910	1·89	8·78	11·09	0·11	5·02	33·53	5·92	5·68	9·46	10·77 (3)	15·1 + *x* (156)	—
193 K	*Chelmsford.* From ten yards above Stoneham's weir, 4,100 feet below effluent outfall (an average sample).	Nov. 21, 1910	Nov. 30, 1910	1·31	5·47	2·85	0·08	3·13	25·12	0·38	0·64	1·52	2·20	6·9 (? + *x*) (223).	—
	South Delph.														
123 K	*Lincoln.* From South Delph, 10 yards above outfall (an average sample).	Nov. 24, 1910	Dec. 5, 1910	0·73	15·80	2·65	0·18	9·03	15·43	1·32	1·96	2·45	3·64	14·0 (218)	17·4§
	Canal.														
128 K	*Berkhamsted.* From twenty	Jan. 9, 1911	Jan. 12, 1911	—	7·89	1·43	—	4·51	27·36	2·37	—	—	—	—	12·8

TABLE. I.—Analysis of Various Samples of River Muds.

All figures expressed as parts per cent.

				Calculated on the *wet* mud.			Calculated on the *dry matter* of the mud.															
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	
Number of sample.	Place.	Date when drawn.	Date of analysis.	Moisture at 105° C.	Volatile matter.	Non-volatile matter.	Volatile matter.	Non-volatile matter.	Matter insoluble in hydrochloric acid (after ignition).	Total phosphorus. (*P*)	Total iron. * (*Fe*)	Total sulphur (*S*)	Sulphur present in some other form than sulphide (probably sulphate). (*S*)	Sulphur required to form sulphide with the iron present. (*S*)	Oxygen absorbed from $\frac{N}{8}$ permanganate at 27° C. (80° F.) in 4 hours.	Total nitrogen (by Kjeldahl). (*N*)	Oxygen taken up from tap water:—				Oxygen taken up from still water in Adeney apparatus at 18° C. in 650 days.	—
																	at 18° C. in			At air temperature in		
																	24 hours.	48 hours.	5 days.	156 to 225 days.		
304	R. Anker. *Nuneaton.* Taken below outfall (average of 12 samples).	Oct. 12, 1910	Oct. 20, 1910	76·27	3·63	20·10	15·31	84·69	72·32	0·26	1·24	0·95	trace	0·71	4·57	0·674 0·686	—	—	0·50	1·91 ap.† (225 days)	3·14	The sluggish reach from which this mud was taken was in doubtful condition, the water being deoxygenated and dark in appearance. The green algæ in the reach were swarming with insect life, etc.
305	*Nuneaton.* From above outfall (chance sample).	Oct. 12, 1910	Dec. 16, 1910	80·17	3·25	16·58	16·36	83·64	66·81	—	—	1·09	—	—	10·52	0·796 0·819	2·00	2·31 (3 days)	2·61	—	—	This sample was drawn from a sluggish reach in doubtful condition and showing some grey growth. It contained a few shrimps, which were not picked out when the analysis was made, the mud having then a putrid odour.
306	R. Avon. *Coventry.* From above outfall at Ryton Bridge (average of 12 samples).	Oct. 13, 1910	Oct. 18, 1910	75·42	2·87	21·71	11·69	88·31	63·62	0·13	1·03	0·54	0·13	0·59	3·79	0·474 0·486	—	—	0·19 (6 days)	1·80 ap. (169 days)	1·68	This sample was black and gritty, with a sea-weed smell. It was drawn from a very sluggish reach, in clean condition, the water being clear and practically odourless.
307	*Coventry.* From above outfall at Ryton Bridge (average of 3 samples).	Oct. 12, 1910	Dec. 16, 1910	75·41	3·00	21·59	12·20	87·80	63·47	—	—	0·69	—	—	5·63	0·521 0·537	1·07	1·22 (3 days)	1·48	—	—	This sample was putrescent and greyish black when analysed. It was drawn at the same time and from the same reach as sample No. 306, but was analysed much later.
09	*Coventry.* From below outfall at Rock Spinney (average of 3 samples).	Oct. 13, 1910	Oct. 19, 1910	77·77	2·84	19·38	12·79	87·21	72·28	0·23	1·83	1·17	0·06	1·05	5·27	0·651 0·651	0·71	0·97	1·41 (6 days)	2·94 (166 days)	3·17	From a very sluggish reach in bad condition. Water deoxygenated and swarming with insect life; grey growth.
308	*Coventry.* From below outfall at Bubbenhall up to Rock Spinney (average of 15 samples).	Oct. 13, 1910	Oct. 17, 1910	83·37	2·84	13·78	17·10	82·90	59·72	0·36	1·86	2·00	trace	1·06	7·35	0·762 0·812	—	—	1·48 ap.	4·93 + *x*‡ (189 days)	5·54	This sample was drawn from a very sluggish reach, in bad condition. Water deoxygenated; grey growth; green algæ; aquatic life in great abundance.
x	*Coventry.* An average sample from below outfall near the further end of Rock Spinney (towards Bubbenhall Mill).	April 25, 1911	April 27, 1911	83·70	2·99	13·31	19·35	81·65	63·10	0·33	1·16	0·82	0·06	0·66	7·25	0·92 0·87	0·72	0·82	1·59	—	—	River in bad condition here. When analysed, the sample of black mud had little smell. It contained a few worms and a good deal of decayed leafy matter.
y	*Coventry.* Scum from river taken from the same reach as mud "*x*."	April 25, 1911	April 27, 1911	96·00	4·00		—	—	38·00	—	0·61	0·72	—	—	—	—	—	—	—	—	—	
192 K	R. Chelmer. *Chelmsford.* From five yards below effluent outfall (an average sample).	Nov. 21, 1910	Nov. 28, 1910	79·62	3·88	16·50	19·03	80·97	67·15	0·36	1·67	2·11	0·02	0·95	6·38	1·111 1·143	1·08	1·80	2·05 (3 days)	2·87 + *x* (156 days)	—	From a sluggish reach in poor condition, the river being higher than usual. The mud was black.
193 K	*Chelmsford.* From ten yards above Stoneham's Weir, 4,100 feet below effluent outfall (an average sample).	Nov. 21, 1910	Nov. 30, 1910	59·15	5·01	35·84	12·26	87·74	69·82	0·16	0·67	0·35	0·01	0·38	3·08	0·045 0·048	0·08	0·18	0·26	0·85 (? + *x*) (223 days)	—	From a sluggish reach in moderate condition. The sample contained much clay from the river-bed and also some black sand and shells.
123 K	South Delph. *Lincoln.* From South Delph, 10 yards above outfall (an average sample).	Nov. 24, 1910	Dec. 5, 1910	46·75	5·83	47·42	10·95	89·05	76·47	0·08	1·73	0·29	0·02	0·99	1·69	0·140 0·150	0·22	0·27	0·40	1·53 (218 days)	1·90§	When analysed, this sample was black and gelatinous.
128 K	Canal. *Berkhamsted.* From twent yards below outfall (an average sample).	Jan. 9, 1911	Jan. 12, 1911	60·26	4·43	35·31	11·15	88·85	67·90	—	0·88	0·16	—	—	2·98 3·12	0·257 0·270	—	—	—	—	1·43	The canal water was in moderate condition only. The sample of mud was brown in colour. It was a very fine mud, with many red worms (mostly dead) and empty shells, etc. The whole was sieved through a fine zinc sieve (holes about 0·5mm.—not larger) and the mud that went through was taken for analysis.

* *i.e.*, Iron soluble in cold dilute hydrochloric acid.

† "Ap." signifies "approximately."

‡ "+ *x*" means that the oxygen was exhausted.

§ Not still water; the mixture in this case was shaken periodically.

(g) DISSOLVED OXYGEN ABSORPTION FROM EXCESS OF WATER OVER A LONG PERIOD OF TIME.

The "long aerations" were done in quarter-Winchester bottles, of 589 to 743 cc. capacity (one of them 451 cc.), provided with well fitting glass stoppers, the stoppers being tied down with tape and mercury-jointed. The amount of mud to be taken for an estimation must again necessarily vary (in three out of the eight determinations made, the oxygen was exhausted, and in other three nearly exhausted). It is difficult to be precise on this point, but, speaking generally, and calculating on the *dry matter* of the mud, less than 0·1 gramme of this for a bottle of 600 to 700 cc. should be taken in the case of a mud which is expected to absorb much oxygen, although up to 0·5 gramme may be taken in the case of a mud which is expected to absorb comparatively little. For very foul muds, like some of those tested, it might be better to use half-Winchester quart bottles. It is best to weigh out a sufficient quantity of the mud (in which the moisture content is being determined at the same time) for, say, about 2,000 cc. of water at 18° C., contained in a flask of somewhat greater capacity than this, and, after as rapid but quiet mixing as possible, to fill the quarter-or half-Winchester which is to be kept stoppered and jointed (preferably at about 18° C.).

At the end of the period allowed for the "long aeration" (in the above cases 156 to 225 days), the gases which collect at the top of each bottle are transferred and analysed, and the necessary correction is made for the oxygen that they contain.*

(h) DISSOLVED OXYGEN ABSORPTION FROM STILL WATER IN CONTACT WITH AIR.

When a very small quantity of mud is allowed (as in the foregoing "aerations") to remain in contact with excess of oxygen in solution in water, the mud has every chance given to it to oxidize as quickly as it can. But this does not represent the actual state of matters for muds deposited in the quieter reaches of a stream. There, the deeper the layer of mud, the less opportunity will there be for the lower strata to come in contact with oxygenated water, until, if its depth is great enough, the conditions towards the bottom become mainly or wholly anaerobic, as shown by the bubbles of marsh gas and sulphuretted hydrogen which the mud then gives off.

It was therefore thought advisable to make some determinations of the rates at which muds take up oxygen from water under still conditions, the volume of water used being comparatively small, but the water being all the time in contact with air and being thus kept thoroughly oxygenated.

For this experiment the small apparatus designed by Dr. Adeney, which is described in the Fifth Report, Appendix VI., p. 438, has been employed—one apparatus for each sample. The six separate apparatus, together with a seventh containing water alone, which was added later,† have been kept in a water thermostat at 18° C. (65° F.),‡ being only taken out for a short time when the water in any one apparatus rose to the top of the graduated tube (*a*), in order to recharge the whole with fresh air. This recharging was of course more frequent in the earlier than in the later stages of the experiment, its frequency naturally depending on both quality and quantity of mud. The apparatus containing the six muds, about to be discussed, have been severally charged about 15 to 30 times in the course of two years.

The six muds tested in this way were Nos. 304, 306, 308, 309, 123 K and 128 K. The approximate depths of the muds in the various apparatus ranged from 1·4 to 3 cm. (½-inch to 1¼-inch), while the depths of the waters over the muds were 3·0 to 4·2 cm. (1¼-inch to 1⅝-inch). Throughout the experiment (which is still proceeding at the time of writing, December, 1912), all the apparatus but one have been kept quite still, so as to imitate the conditions in a quiet reach of water; the exception is that containing mud No. 123 K, which has been shaken from time to time.

Frequent readings have been made of the absorption of oxygen in each apparatus (73 readings for No. 128 K and 103 to 112 readings for the others, up to 18th November, 1912). A few of these (some with small interpolations) are now given in Table III.

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* This transference, which may be rather troublesome, is best done as follows :—

The mercury of the joint is poured off, the rubber tube carefully removed, and the tape binding the stopper cut, the bottle being held slanted, so that the gas bubble may lodge in the shoulder. The stopper is now almost invariably very firmly fixed (there being a slight vacuum in the bottle), and it does not always yield to tapping. In that case a few drops of water should be poured on the top of the neck at the stopper, or the bottle should be inverted, with its neck in water for a few minutes. After taking out and drying, the stopper will now in all probability be amenable to tapping, though sometimes the aid of a Bunsen burner is required. All this time (of tapping, etc.) the bottle must have been held slanting; further, when the stopper is being tried, to see whether it has become loosened, this has to be done very carefully, otherwise a little air may be sucked into the bottle (as is seen by the tiny bubbles rising through the water in the neck). The bottle is then inverted over mercury in a trough, the stopper removed, and the gases drawn into a suitable mercury gas-holder. For the transference from the quarter- or half-Winchester, a narrow tube of "gum elastic," about 2·5 mm. internal diameter and 33 to 35 cm. (13 inches to 14 inches) long, fixed into a wider rubber tube connecting with the small gas-holder, is most convenient. The former is of the small diameter required, and is sufficiently rigid (without being too much so) to remain steady in the inverted bottle.

Again, in making the estimation of the oxygen remaining in the water of the quarter-Winchester from which the gases have just been carefully removed, the bottle now contains a little mercury (which has filled up the slight vacuum and which has also replaced the small quantity of water unavoidably transferred along with the gases). This mercury has no action upon any of the reagents used in the oxygen determination, until the stage of liberating iodine is reached. Immediately the iodine has been liberated, however, the greater portion of the liquid is poured off, for titration, into a smaller bottle of known capacity (say 350 cc.), *i.e.*, the iodine-containing water and mercury are not allowed to remain in contact. If they are, the estimation is spoilt. The few seconds of time that the two layers are in contact in the quarter-Winchester introduces no appreciable error; this has been investigated by us.

What has just been said in this note applies also, of course, to any "long aeration"—whether of mud, sewage liquor, or effluent, etc.

† The object of setting up a "blank" apparatus, containing nothing but water and air, was of course to see whether the two rubber stoppers and the rubber-vaseline grease used for the glass taps took up any oxygen. This apparatus has been under observation for 2 months (October 15th to December 19th, 1912), without showing any absorption. Rubber stoppers no doubt vary in quality, but it is hardly likely that any would absorb oxygen in quantities at all comparable with those taken up by the muds.

‡ The temperature did not vary more than a fraction of a degree, excepting during very warm summer weather, when it rose a little (no record of this was kept, but the rise was probably never more than about 3° C., at the outside).

TABLE III.—SHOWING A FEW OF THE READINGS OF THE SIX ADENEY APPARATUS, EXPRESSED IN PARTS BY WEIGHT OF OXYGEN TAKEN UP PER 100,000 OF DRY MATTER OF MUD.

Days.	Sample No. 304.	Sample No. 306.	Sample No. 308.	Sample No. 309.	Sample No. 123 K.	Sample No. 128 K.
10	6	27	57	4	83	75
20	96	90	313	54	185	141
50	277	324	1,160	278	487	326
100	712	568	2,267	576	803	507
150	967	750	3,015	794	1,138	653
200	1,300	894	?*	1,040	1,265	805
300	1,800	1,117	4,055	1,508	1,506	1,016
400	2,230	1,285	4,600	2,200	1,652	1,151
500	2,630	1,453	5,107	2,657	1,759	1,278
600	2,940	1,612	5,413	3,040	1,860	1,389
650	3,135	1,678	5,540	3,171	1,902	1,432
700	3,270	1,735	5,630	3,290	1,949	—
750	3.384	1.828	5,800	3.353	—	—

* The apparatus showed hardly any absorption of oxygen for 6 weeks at this time and then it made a sudden jump; this was no doubt due to a stoppage caused by grease in one of the glass taps.

Both the relative and actual rates of absorption, calculated on the *dry matter* of the muds, are seen almost at a glance in Diagram G. The two extremes are Nos. 128 K and 308, the latter having taken up about four times as much oxygen as the former.

It is perhaps fairer, though still not absolutely correct, to compare the relative absorptions by equal weights of the *volatile matter* of the muds, the volatile matter being an approximate measure [†] of the organic matter present. This comparison gives the absorption by No. 308 as nearly two-and-a-half times that of No. 128 K, these being still the two extremes. This is shown in Table IV., in which all the absorptions are given for equal periods of 650 days.

TABLE IV.—SHOWING THE ABSORPTION OF OXYGEN IN 650 DAYS, AS CALCULATED ON (*a*) THE DRY MATTER; AND (*b*) THE VOLATILE PORTION OF THE DRY MATTER OF THE MUDS.

Experiment begun.	Mud sample No.	Approximate depth of mud (cm.)[‡].	Approximate depth of water above mud (cm.).	Percentage of dry matter in mud.	Parts by weight of oxygen taken up by 100 parts of dry matter.	Percentage of volatile matter in the dry mud.	Parts by weight of oxygen taken up by 100 parts of volatile matter of mud.
Oct. 20, 1910 -	304	1·4	3·0	23·7	3·14	15·3	20·5
Oct. 13, 1910 -	306	1·2	3·0	24·6	1·68	11·7	14·4
Oct. 13, 1910 -	308	0·5	3·7	16·6	5·54	17·1	32·4
Oct. 13, 1910 -	309	1·2	3·0	22·2	3·17	12·8	24·8
Dec. 5, 1910 -	123 K.	3·0	4·2	53·3	1·90	11·0	17·4
Jan. 13, 1911 -	128 K.	0·7	4·1	39·7	1·43	11·2	12·8

It is interesting to compare, on Diagram G and on Tables III. and IV., Nos. 306, 309, and 308. No. 306 represents the mud of the river Avon at Ryton Bridge, just above the Coventry outfalls and about 13 miles below the Rugby outfalls. There are only a few small discharges of polluting liquid between the lowest Rugby outfall and Ryton Bridge, and at this latter point the water of the river has again become as pure as it is above the Rugby sewage works and farm (*cf.* this Appendix, p. 65). No. 309 represents the mud shortly below the second (at that time the lowest) Coventry outfall, while No. 308 is mud from about ¾ to 1¼ miles below this outfall, taken from deep still water in which the mud had been able to accumulate to a considerable depth in places.

The relative absorptions of oxygen over a period of 650 days, as calculated on the volatile matter of the muds, are 14·4, 24·8 and 32·4. In other words, the organic matter (including sulphide) of the mud above the Coventry outfalls, itself partly derived from sewage matter which had had the benefit of a long stretch of river for purification, took up only three-fifths as much oxygen as the organic matter of the mud shortly below the second outfall, and only three-sevenths as much as the organic matter of the mud accumulated a little lower down.[§]

The organic matter of the Nuneaton mud, No. 304, drawn below outfall, also shows rather high oxygen absorbing power (20·5); that of the Lincoln mud, No. 123 K, drawn 10 yards above outfall, somewhat less (17·8); while the organic matter of the Berkhamsted mud, No. 128 K, drawn shortly below outfall, took up less oxygen than any of the others tested in this way (12·8), the reason no doubt being that this last mud is being constantly stirred up by passing barges and thus given more opportunity for oxidation.

A few further notes may be added with regard to the other samples of mud whose analyses are given in Tables I. and II., but which were not tested for rate of oxidisability over a long period.

No. 307 (from above the Coventry outfalls) is comparable with No. 306, both having been drawn from the same spot, though No. 307 represents a smaller average of subsamples. Unfortunately, it could not be examined for 2 months, during which time it must have undergone some anærobic decomposition, though kept in ice; this shows itself in the markedly higher figure for dissolved oxygen absorption in 5 days. The two samples are otherwise fairly alike.

No. X, a sample of mud drawn below the Coventry outfalls, between Bubbenhall and Rock Spinney, 6 months after Nos. 309 and 308, contained less iron and sulphur than the two latter, but rather more nitrogen. It was on the whole very like No. 308.

No. Y, the scum drawn from the river at the same time and place as No. X, consisted mainly of organic matter and was potentially very polluting, *i.e.*, if it were to suffer eventual decomposition and be deposited as mud.

No. 305, a single sample of Nuneaton mud, from above outfall, was drawn at the same time as No. 304, the average sample from below outfall. It had to be kept in ice for 2 months before it could be examined; but, allowing for the anærobic changes which it must have undergone during this time, it does not appear to have differed

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(†) This is, of course, only approximate; thus, when the dry matter of a mud is ignited, any sulphide of iron ($Fe\ S$) present changes into sesquioxide ($Fe_2\ O_3$) and, in doing so, loses 9 per cent. by weight.

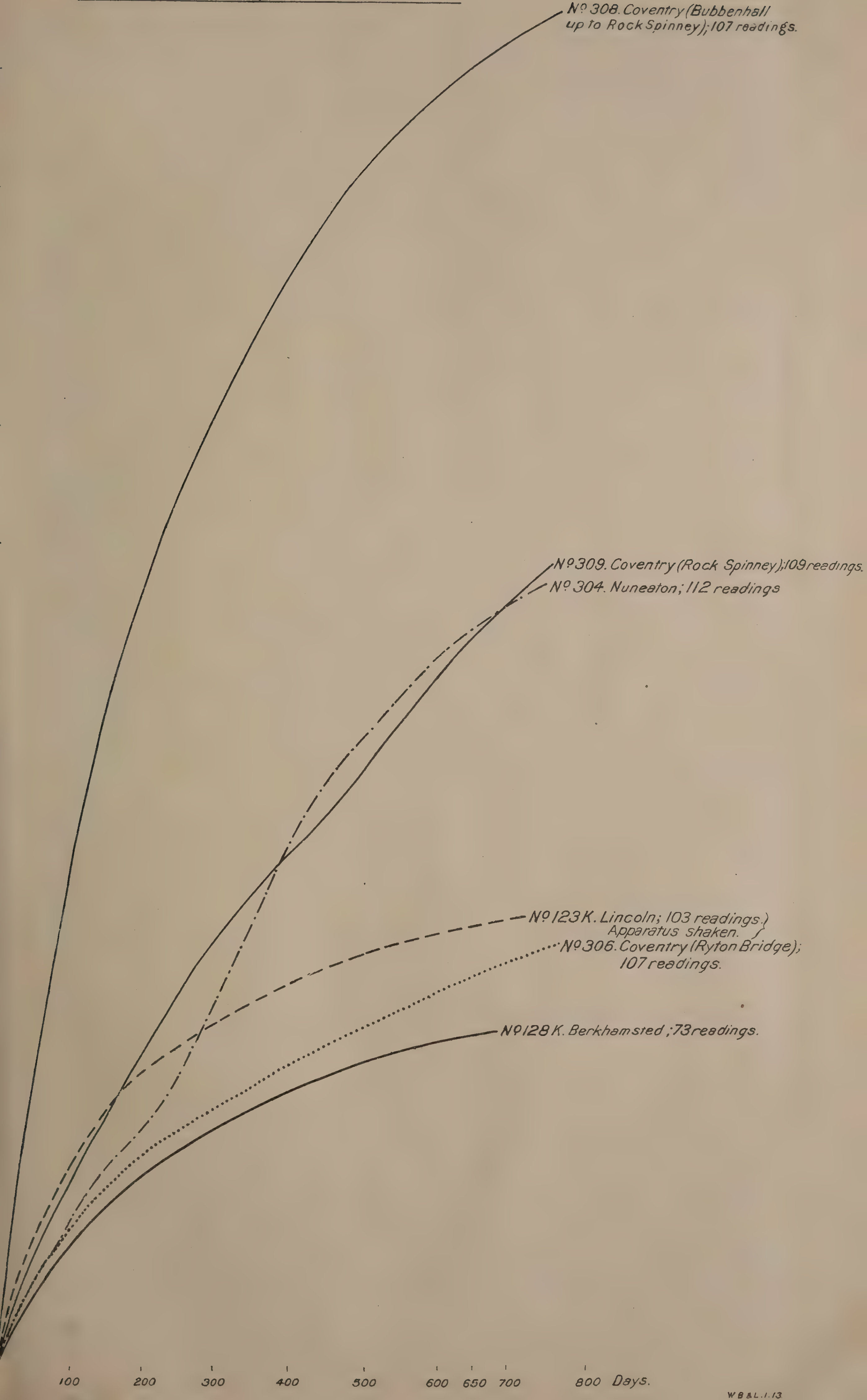
(‡) 1 cm. = about 0·4 inch.

[§] Since the above observations were made, the area of land available for sewage purification at the Coventry farm has been much extended, in view of the abnormally rapid increase of population.

DIAGRAM G.

RIVER MUDS.

Parts by weight of oxygen taken up in Adeney apparatus by 100,000, parts of the dry matter of the mud.



greatly from No. 304, and was of a very polluting character. In explanation of this it may be stated that the river Anker is considerably polluted above the Nuneaton outfall.

The two muds drawn at Chelmsford, No. 192 K (taken just below effluent outfall) and No. 193 K (taken ¾ of a mile below it), showed marked differences in composition, greatly in favour of the lower sample. While No. 192 K was highly polluting, No. 193 K took up oxygen much less rapidly.

The two remaining muds, No. 123 K, from the South Delph at Lincoln, and No. 128 K, from the canal at Berkhamsted, have already been adverted to. Compared with the worse samples of Coventry and Chelmsford muds and the samples from Nuneaton, they are comparatively clean. One point, however, is noteworthy, viz., No. 123 K shows distinctly lower figures for "oxygen aborbed" from permanganate in 4 hours and for nitrogen, but higher figures for iron and sulphur than No. 128 K. A comparison of the amounts of oxygen taken up in the two Adeney apparatus by these muds is hardly valid, seeing that the Lincoln one was shaken and the other not. Judging from the two curves, however, in Diagram G, the Berkhamsted mud had rather less power of taking up oxygen from water (in agreement with the lesser sulphur content).

Though it was of course to be expected, it is interesting to note that in every case where estimations of dissolved oxygen absorption by the muds were made by the two methods :—

> (*a*) allowing the mud to remain in a stoppered and mercury-jointed bottle in contact with a large volume of water containing oxygen in solution ;
>
> (*b*) allowing it to remain in contact, in the Adeney apparatus, with a small quantity of water, with plenty of air above it, this air being frequently renewed ;

more oxygen was invariably taken up in (*a*) than in (*b*), the periods of time being the same in both cases, thus :—

TABLE V.

Sample.	Time (days).	Parts of oxygen, by weight, per 100 parts of dry matter of mud, taken up in :—	
		(*a*) Long aeration bottle.	(*b*) Adeney apparatus.
No. 304 (Nuneaton) - - - - - - -	225	1·91 ap.	1·47
No. 306 (Ryton Bridge) - - - - - -	169	1·80 ap.	0·83
No. 308 (Bubbenhall to Rock Spinney) - - - -	189	4·93 + x	3·4
No. 309 (Rock Spinney) - - - - - - -	166	2·94 ap.	0·84 0·83
No. 123 K. (Lincoln) - - - - - - -	218	1·53	1·22 (shaken)

In every instance of (*a*), even when all the oxygen in the diluting water had been used up, the residual mud had become pale brown in colour, from oxidation of the iron present.

To give a more or less concrete idea of the deoxygenating effect of such muds on still water, as exemplified by the water in the Adeney apparatus, we may consider the two extreme cases, Nos. 128 K and 308.

In 650 days, 100 grammes of the dry matter of these muds took up, respectively :—

No. 128 K - -	1·43 grammes oxygen.	
No. 308 - -	5·54 "	"

Water, thoroughly oxygenated at ordinary temperature, contains in solution about 7 cc. of oxygen per litre, or 1 part by weight of oxygen per 100,000 of water.

100 grammes of the dry matter of No. 128 K would thus have completely deoxygenated 143 litres (143,000 grammes) of water, and 100 grammes of wet mud 56·6 litres of water, in 650 days.

100 grammes of the dry matter of No. 308 would have deoxygenated 554 litres of water, and 100 grammes of the wet mud 92 litres of water, in the same period of time.

If we confine ourselves to the first 150 days, we find that 100 grammes of the wet mud of No. 128 K would have completely deoxygenated 25·8 litres of water, while 100 grammes of the wet mud of No. 308 would have deoxygenated 50 litres. In other words, 1 gramme of each of these wet muds, deposited in a shallow layer in still water, would have deoxygenated, per day, over a period of 150 days, 1·72 and 3·3 grammes of fully aerated water. Since the specific gravity of mud is greater than that of water, the figures for deoxygenation would be higher if given in terms of *volume*.

A river water taking up 0·2 part by weight of oxygen per 100,000, of water in 5 days at 18° C. may be considered as representing approximately the average quality of our "clean" streams, while 0·5 part by weight of oxygen taken up in the same time represents a stream in "doubtful" condition (*cf.* this Appendix, Section 6, p. 136).

100,000 grammes of a "doubtful" water would therefore take up in 1 day 0·1 gramme of oxygen, *i.e.*, an amount of oxygen equivalent to the complete deoxygenation of 10,000 grammes of a fully aerated water.

Weight for weight, therefore, the deoxygenating powers of the two (wet) muds, Nos. 128 K and 308, are (for 150 days) 17·2 and 33·3 times as much as the deoxygenating power of a "doubtful" water.

Again, the deoxygenating powers of these two muds are—weight for weight—about 4·3 and 8·3 times as great as that of an effluent of moderate quality—an effluent which takes up 2·0 parts by weight of oxygen, per 100,000, of effluent in 5 days.

We have no data showing the volume or weight of mud in any given reach of stream, relatively to the volume of water which flows over it daily, but we think that the figures which have just been given emphasise sufficiently the marked and *continuously* deteriorating effect of such muds on the water of streams, and therefore the necessity for preventing their accumulation, if the streams are to remain reasonably clean.

If a putrefactive mud, such as the above, accumulates for some time in a quiet reach of stream and is then disturbed by an increased flow, which is just sufficient to stir up the mud without carrying it quickly down stream, its deoxygenating effect must obviously be much increased for the time being.

There are too few data to allow of an absolute statement as to how far the determination of the more rapidly oxidizable organic matter† of a mud gives an indication of its total power of absorbing oxygen (and, besides, the muds in the various Adeney apparatus are still going on absorbing oxygen at different rates—December, 1912). But, taking the few data we have, viz. :—

TABLE VI.

(*a*) Mud. No.	(*b*) Dissolved oxygen absorption from excess of water in 5 days.	(*c*) Dissolved oxygen absorption in Adeney apparatus in 650 days.	Ratio of *b* : *c* (*b* = 1).
308	8·67 ap.	32·4	1 : 3·7 ap.
309	11·02	24·8	1 : 2·5
304	3·25	20·5	1 : 6·3
123 K.	3·64	17·4 (shaken)	1 : 4·8
306	1·34 ap.	14·4	1 : 10·7 ap.

† As already explained on p. 150, "organic matter" is here intended to include the sulphide of iron present.

it is evident that muds containing much readily oxidizable matter show the higher ratio between the 5 days' and the long oxidation tests. In other words, after the first portion of oxidizable matter of a foul mud has become oxidized, the rate of oxidation of the remaining oxidizable matter tends to abate. This is shown graphically in Diagram G.

Comparing (*for the organic, i.e., the volatile matter of the muds*) the figures for "oxygen absorbed" from permanganate in 4 hours with those for oxygen taken up from water and air in 650 days, we have :—

TABLE VII.

(*a*) Mud. No.	(*b*) "Oxygen absorbed" from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.).	(*c*) Dissolved oxygen absorption in Adeney apparatus in 650 days at 18° C. (65° F.).	(*d*) Ratio of *c* : *b* (*c* = 1).
308	42·9	32·4	1 : 1·3
309	41·2	24·8	1 : 1·7
304	29·9	20·5	1 : 1·5
123 K.	15·4	17·4	1 : 0·9
306	32·4	14·4	1 : 2·3

Beyond noting that very polluting muds appear to show a fairly constant ratio between the two tests, no deductions can be drawn here.

Further, comparing (for the organic matter of all the muds) the figures for "oxygen absorbed" in 4 hours and dissolved oxygen absorption in 5 days, we get :—

TABLE VIII.

(*a*) Mud. No.	(*b*) Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.).	(*c*) Dissolved oxygen taken up from water in 5 days at 18° C. (65° F.).	(*d*) Ratio of *c* : *b* (*c* = 1).
305	64·3	16·0	1 : 4·0
307	46·2	12·2	1 : 3·8
308	43·0	8·7 ap.	1 : 4·9 ap.
309	41·2	10·2 ap.	1 : 4·0 ap.
x	37·5	8·2	1 : 4·6
192 K.	33·5	13·0 ap.	1 : 2·6 ap.
306	32·4	1·3 ap.	1 : 24·9 ap.
304	29·9	3·3	1 : 9·1
128 K.	27·4	—	—
193 K.	25·1	2·2	1 : 11·4
123 K.	15·4	3·6	1 : 4·3

The figures in the table which has just been given indicate, broadly (though with some apparent discrepancies), that in muds of a highly polluting character the ratio of the 5 days' dissolved oxygen absorption to the 4 hours' permanganate absorption is higher than in those of a less polluting nature. Oxidation of such muds by permanganate is very much more rapid than oxidation by air, and this is more especially the case in the less impure muds. For river muds, therefore, the permanganate test does not appear to be a delicate index of quality.

Nitrogen.—The (*volatile matter* of the) muds showed the following percentages of nitrogen (the figures for the 5 days' dissolved oxygen absorption and the 4 hours' permanganate absorption being again given in the appended table for purposes of reference) :

TABLE IX.

(*a*) Mud.	(*b*) Nitrogen.	(*c*) Dissolved oxygen taken up from water in 5 days at 18° C. (65° F.).	(*d*) Ratio of *b* : *c* (*b* = 1).	(*e*) Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 27° C. (80° F.).	(*f*) Ratio of *b* : *e* (*b* = 1).
No. 305	4·94	16·0	1 : 3·2	64·3	1 : 13·0
No. 307	4·34	12·2	1 : 2·8	46·2	1 : 10·6
No. 308	4·60	8·7 ap.	1 : 1·9 ap.	43·0	1 : 9·3
No. 309	5·09	10·2 ap.	1 : 2·0	41·2	1 : 8·1
x	4·65	8·2	1 : 1·8	37·5	1 : 8·1
No. 192 K.	5·92	13·0 ap.	1 : 2·2	33·5	1 : 5·7
No. 306	4·11	1·3 ap.	1 : 0·3	32·4	1 : 7·9
No. 304	4·44	3·3	1 : 0·7	29·9	1 : 6·7
No. 128 K.	2·37	—	—	27·4	1 : 11·6
No. 193 K.	0·38	2·2	1 : 5·8	25·1	1 : 66·1
No. 123 K.	1·32	3·6	1 : 2·7	15·4	1 : 11·7

One striking fact comes out in the above table, viz., that in eight of the eleven samples the nitrogen (calculated on the volatile matter of the mud) only varied between 4·44 and 5·92 per cent., the second highest figure being 5·09, and the average for the eight 4·76. In the remaining three samples the nitrogen was much lower. The average percentage of nitrogen for the eight *wet muds* themselves works out at 0·7 per cent., consequently such muds have a certain small value as nitrogenous manures.

There appears to be nothing like a constant ratio between the nitrogen (= 1) and the dissolved oxygen taken up by the mud from water in 5 days, though in the majority of cases this ratio varied between 1 : 2 and 1 : 3 ; * nor, in the five muds available for comparison, is there anything like a constant ratio between the nitrogen and the dissolved oxygen taken up in the Adeney apparatus in 650 days.† Further, there is nothing like an even ratio between the nitrogen and the oxygen absorbed from permanganate in 4 hours. All that can be safely said here is that a highly nitrogenous mud will usually be found to be capable of taking up much oxygen.

Iron.—The iron in eight of the nine muds in which it was estimated was present almost entirely as sulphide of iron, the chief exception being No. 123 K, which yielded the highest figure for iron, and in which the latter was for the most part present in some other form than sulphide (no doubt basic carbonate). No. 123 K was drawn slightly above the outfall at Lincoln, and not very far below the discharge of some engineering works. As calculated on the *volatile matter* of the muds, the percentage of iron varied from 5·5 to 15·8, six of the samples ranging from 5·5 to 8·8. On the whole, therefore, the variations were not excessive. As a rule, the muds contained two to three times as much iron as nitrogen, though there was no definite ratio between the two sets of figures. Neither was there any ratio between the amount of iron and the oxidisability of the mud, either in 5 days or over a prolonged period.

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* Something like 1 : 2 is probably the more correct ratio here, because Nos. 305 and 307 had to be kept for 2 months before being analysed, and hence their figures for dissolved oxygen absorption in 5 days are higher than the reality.

† We have not yet been able to test how far the nitrogen of the muds in these several apparatus has undergone nitrification, as the absorption of oxygen is still proceeding (December, 1912).

Phosphorus.—The actual quantity of phosphorus in the muds was but small, varying from 0·73 to 2·11 per cent. (calculated on the *volatile matter* of the muds). The phosphorus did not show much variation in quantity. As a rule, it amounted to about one-third or a little more (by weight) of the nitrogen, and it was present in largest quantity in the more polluting muds, *i.e.*, in those which were capable of taking up most oxygen. Still, though the figures obtained are of interest, the variation in quantity shown by the phosphorus in the different muds is hardly wide enough to make the estimation of great value as a criterion of the quality of a mud.

Sulphur.—This was present in comparatively large quantity in most of the muds; calculated on the *volatile matter* of the mud, it ranged from 1·43 to 11·69 per cent. As already stated, it was present almost entirely as sulphide in seven of the eight muds tested for this; in the eighth of those samples (No. 306, from Ryton Bridge, Coventry, one of the less impure muds, but not analysed until 5 days after drawing), about one-quarter of the sulphur was present in other form, no doubt sulphate, for the most part. The greatest amounts of sulphur were undoubtedly to be found in the most polluting muds.

As is well-known, the iron of finely-divided sulphide of iron undergoes oxidation very readily, and consequently the first deoxygenating effect of a putrefactive mud upon the supernatant water must be largely due to this. We have not actually determined the proportions of oxygen taken up during the early stages of oxidation by (*a*) the sulphide of iron, and (*b*) the carbonaceous matter of a mud, though it would be desirable that this should be done eventually. But the comparatively quick change in colour of a foul mud from black to brown, when it is brought into contact with excess of dissolved oxygen in water, leaves no doubt as to the rapid oxidation of the iron. Theoretically, for the oxidation of the iron (assuming the sulphur of the sulphide of iron to be set free and not *immediately* oxidized), 0·75 part by weight of oxygen will be taken up for 1 part by weight of sulphur present as sulphide of iron. Further, that this oxygen is taken up rapidly under favourable conditions, is seen by comparing the available figures (as calculated on the volatile matter of the muds) for dissolved oxygen taken up from excess of water in 24 hours, 48 hours, and 5 days :—

Table X.

	Sulphur present as sulphide when mud was analysed.	Dissolved oxygen taken up at 18° C. in :—			Oxygen required to oxidize completely the iron combined with the sulphur as sulphide.
		24 hours.	48 hours.	5 days.	
No. 192 K.	10·98	5·68	9·46	13·0	8·2
No. 309	8·68	5·55	7·60	10·2	6·5
x	3·92	3·72	4·23	8·2	2·9
No. 193 K.	2·77	0·61*	1·52	2·2	2·1
No. 123 K.	2·57	1·96	2·45	3·6	1·9

The work on river muds detailed in this paper is far from being exhaustive. It requires, *e.g.*, to be supplemented by observations on the muds of streams which are known to be free from pollution by sewage liquor and effluent. We trust, however, that it may prove of sufficient interest to lead to further work on the subject.

Comparison of the Amounts of Oxygen taken up from Still Water by Muds of Equal Surface Area and Approximately Equal Depth.

Mr. Tatham has suggested that the rate of absorption of oxygen from water, *per unit surface area* of a mud, is perhaps of more importance than the absorption per unit weight; and this is probably true, so long as the mud remains undisturbed in the stream. The absorption experiments, carried out as described above, only allow of a partial comparison of the muds in this respect, seeing that the depths of the muds in the various apparatus were unequal, besides that the layers were all (of necessity) shallow (*cf.* Table IV.). Each mud had an exposed surface area of about 23 square centimetres (= 9 square inches). †

Three of the muds with approximately equal depths, Nos. 304, 306 and 309, can, however, be compared, thus :—

Mud sample. No.	Approximate depth of mud (c.m.).	Grms. of oxygen taken up per square metre of mud in :—				
		(*a*) 14 days.	(*b*) 50 days.	(*c*) 100 days.	(*d*) 150 days.	(*e*) 650 days.
304	1·4	0·83	6·7	11·7	23·4	75·0
306	1·2	1·17	8·7	14·6	19·3	42·9
309	1·2	0·17	5·7	11·7	16·1	64·4

If we neglect the figures in column (*a*), which show curious differences, we find that both of the muds, Nos. 304 and 309 [which—weight for weight of dry matter—took up nearly twice as much oxygen in 650 days as No. 306 (*cf.* Table III. and Diagram G.)]. took up per unit of surface area less oxygen than No. 306 in 100 days.

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* This figure is probably rather too low, from too high a dilution having been made.

† The bottles of the various Adeney apparatus, which contained (and still contain at time of writing) the different muds, were as nearly as possible of the same external diameter. Two similar bottles, not in use, were measured, and were found to have an internal cross-section of 23·0 and 22·7 square c.m., respectively.

Muds Nos. 308 and 128K are also roughly comparable, thus :—

Mud sample. No.	Approximate depth of mud (c.m.)	Grms. of oxygen taken up per square metre of mud in :—				
		(*a*) 14 days.	(*b*) 50 days.	(*c*) 100 days.	(*d*) 150 days.	(*e*) 650 days.
308	0·5	1·13	8·3	16·1	21·4	39·2
128K	0·7	2·65	8·1	12·4	16·2	35·6

Here, again, we find that No. 128K., the dry matter of which had only about one-quarter of the actual oxygen absorbing power of that of No. 308 (*cf.* Diagram G), took up per unit of surface area, in periods up to 650 days, much the same quantities of oxygen that the latter did.

The corresponding figures for No. 123K may also be given here, though this mud is not comparable with the others for the point in question, seeing that, on the one hand, its depth was much greater, while, on the other, the apparatus containing it was shaken at frequent intervals, so as to disseminate the mud through the water :—

Mud sample No.	Approximate depth of mud (c.m.).	Grms. of oxygen taken up per square metre of mud in :—				
		(*a*) 14 days.	(*b*) 50 days.	(*c*) 100 days.	(*d*) 150 days.	(*e*) 650 days.
123K	3·0	1·44	9·4	15·6	22·6	37·5

We suggest tentatively, as a probable explanation of these surface area absorptions, that highly polluting organic muds may be more glutinous and therefore less permeable by water than muds of looser grain and smaller actual oxygen absorbing power. If this is correct, it indicates that, so long as deposits of mud remain undisturbed in streams, the largest absorption of oxygen from the water over a given area will be brought about, not by the most actually polluting muds, but by others which are less polluting in the aggregate. The few data available do not allow of our saying more on the subject, excepting to suggest that the matter is one worthy of further experimental investigation.

SUMMARY.

Some of the points in the foregoing paper may be shortly summarized, as follows :

(1) The methods of analysis, given on p. 147, are such as would ordinarily be followed.

(2) For the determination of the dissolved oxygen absorption from excess of water in 24 and 48 hours, 5 days and prolonged periods, the quantities of mud to be taken must necessarily vary. If a guide to this (for any given mud) is desired, a preliminary rapid determination of the amount of sulphur present is perhaps as good as anything else, though no definite rule can be laid down here.

(3) The absorption of dissolved oxygen by polluting muds deposited in still waters may go on for years. In the case of three of the six muds tested in this way the absorption has, so far, continued with comparatively little diminution in rate for 2 years,* but with the other three the rate has slowed down very much.

Of these six muds, the two extremes showed an absorption equivalent to the deoxygenation of 1·7 and 3·3 grammes of fully aerated water per gramme of mud per day, over a period of 150 days. Or, to put it in other terms : the two muds of the six which showed the least and the greatest absorption, effected during this time as much deoxygenation of water as would have been brought about by 17·2 and 33·3 times their weight of a "doubtful" river water (*i.e.*, a water taking up in 5 days at 18° C. 0·5 part by weight of oxygen per 100,000).

So long as muds remain undisturbed in a stream, the absorption of oxygen per unit surface area is apparently greater in the case of the less polluting, *i.e.*, the presumably looser-grained samples, than in the case of the more polluting and probably more closely aggregated ones.

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* This raises the interesting point that the excretal products do not appear to have inhibited bacterial action. The same thing had long ago been observed by one of us in connection with septic tank sludges kept at laboratory temperature in bottles with moderate quantities of water, each bottle having an outlet tube delivering the evolved gas over mercury ; in one case the evolution of gas went on for something like six or more years, apparently with intermittence in the later stages.

SECTION 9.

(Sections 2, 3 and 9 should be read in conjunction.)

THE COLLECTION OF SAMPLES FOR SUBMISSION TO STANDARD TESTS.

In considering this question the Commission need hardly be reminded of the fact that a sound estimate of the strength or character of a sewage cannot be based upon analytical results obtained from a single sample, practically all sewages being subject to very wide variations of strength and volume, not only day by day throughout the week, but hour by hour throughout the day.

These variations in strength and volume of sewage are of course dependent partly upon weather conditions and partly upon other and divers factors.

Variations in strength thus induced are to greater or less extent evened up as the sewage passes through tanks and filters or land, in the course, that is, of purification processes, but they still show to a marked extent in the final effluents.

Exceptions to this rule—such, for instance, as might occur in the case of a very well purified land effluent derived from a dilute sewage—are few and far between.

The following figures may be quoted in illustration of variability in composition of an effluent.

(1) Effluent from the Buxton Outfall Works, where the purification process included chemical precipitation, settlement, straining and percolating filtration.

Eighteen chance samples of final effluent, drawn at varying hours between January, 1909, and July, 1911, gave the following figures among others:—

Parts per 100,000.

Sample drawn.	Jan. 25, 1909.	June 8, 1909.	July 5, 1909.	July 23, 1909.	Aug. 4, 1909.	Sept. 2, 1909.	Oct. 1, 1909.	Oct. 14, 1909.	Oct. 30, 1909.	Nov. 29, 1909.	Dec. 28, 1909.	Jan. 26, 1910.	Feb. 24, 1910.	May 5, 1910.	Feb. 10, 1911.	May 4, 1911.	May 24, 1911.	July 6, 1911.
xygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. -	0·34	1·22	0·70	0·36	0·20	0·56	0·53	0·49	0·58	1·16	0·65	0·60	0·46	0·51	2·38	0·60	—	1·74
issolved oxygen taken up in 5 days at 65° F.	0·43	1·40	0·32	0·09	0·30	0·27	0·27	0·30	0·34	2·05	0·85	1·00	1·10	0·37	3·02	0·67	1·71	2·00
hlorine - - -	2·15	3·93	3·43	3·07	2·70	3·18	3·08	2·62	2·75	3·68	2·80	4·08	2·67	2·48	3·73	2·48	3·80	4·00
olids in suspension -	2·7	6·4	1·7	1·6	1·0	2·0	0·9	1·1	1·1	3·2	1·4	1·7	1·5	2·2	7·5	2·5	3·1	7·4

(2) Effluent from the Rugby Sewage Works, where the sewage is grit-settled, septicised, oxidised in percolating filters, and finally passed over land before being discharged.

Seventeen samples of effluent, drawn at irregular intervals between May, 1909, and June, 1911, gave the following results among others:—

Parts per 100,000.

Sample drawn.	May 12, 1909.	June 16, 1909.	July 14, 1909.	Aug. 12, 1909.	Aug. 20. 1909.	Sept. 10, 1909.	Oct. 12, 1909.	Nov. 8, 1909.	Dec. 9, 1909.	Jan. 10, 1910.	Feb. 3, 1910.	July 5, 1910.	Jan. 23, 1911.	May 15, 1911.	May 23, 1911.	June 2, 1911.	June 20, 1911.
xygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. -	2·51	1·60	1·05	2·40	1·73	1·51	1·31	1·34	0·94	1·28	0·86	3·27	0·96	2·10	2·06	2·29	1·75
issolved oxygen taken up in 5 days at 65° F. - -	1·47	2·95	0·70	2·04	1·61	1·55	3·10	1·45	1·99	0·79	0·79	3·03	0·98	2·90	2·69	1·33	2·08
hlorine - - - -	9·24	10·15	8·05	10·30	11·60	10·54	9·92	9·72	7·50	9·42	6·86	11·50	9·28	10·38	12·15	9·52	12·40
olids in suspension	1·1	1·3	1·2	2·5	—	1·3	—	0·6	—	—	—	8·5	—	2·8	4·2	1·4	0·7

(3) Effluent from the Cambridge Sewage Farm, where the sewage is screened, settled, and filtered through sandy loam before being discharged.

Thirteen samples of final effluent, drawn at irregular intervals between January, 1909, and June, 1910, gave the following figures among others:—

Parts per 100,000.

Samples drawn.	Jan. 20, 1909.	June 23, 1909.	June 23, 1909.	July 22, 1909.	Aug. 20, 1909.	Sept. 18, 1909.	Oct. 18, 1909.	Nov. 16, 1909.	Dec. 17, 1909.	Jan. 18, 1910.	Feb. 17, 1910.	June 23, 1910.	Aug. 12, 1910.
xygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	1·61	1·10	0·81	1·84	1·19	1·20	0·83	1·35	1·01	0·86	1·31	0·82	0·70
issolved oxygen taken up in 5 days at 65° F. - - - - - - -	1·55	0·85	0·54	2·74	1·21	1·20	0·52	1·36	1·28	0·87	1·67	0·34	1·20
hlorine - - - - - -	8·20	9·49	9·49	9·56	8·15	9·30	7·20	8·83	7·44	7·74	7·50	5·39	8·09
olids in suspension - - - -	2·6	3·1	2·8	3·2	2·1	3·2	0·8	1·4	—	3·7	1·7	1·8	1·4

(4) Effluent from the Berkhamsted Sewage Works, where the screened sewage is first septicised and then filtered in double-contact beds.

Fifteen samples of the final effluent, drawn at irregular intervals between July, 1909, and June, 1911, gave the following figures among others :—

PARTS PER 100,000.

Sample drawn.	April 19, 1909.	July 31, 1909.	Aug. 9, 1909.	Aug. 30, 1909.	Aug. 30, 1909.	Sept. 28, 1909.	Oct. 27, 1909.	Nov. 11, 1909.	Nov. 25, 1909.	Dec. 24, 1909.	Jan. 22, 1910.	Feb. 21, 1910.	June 22, 1910.	Feb. 17, 1911.	June 7, 1911.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·72	0·67	0·94	0·56	0·49	2·34	0·77	0·51	0·65	0·73	1·44	1·34	1·86	1·07	0·35
Dissolved oxygen taken up in 5 days at 65° F.	4·65	1·07	2·67	0·48	0·62	4·70	0·90	2·40	—	—	2·61	3·00	2·41	0·93	0·30
Chlorine	4·48	4·48	4·40	1·87	4·59	4·64	3·16	4·32	3·18	3·51	3·97	3·41	3·70	2·97	3·17
Solids in suspension	3·03	1·06	2·01	6·05	1·08	5·00	2·00	—	—	—	4·00	2·08	1·09	0·09	0·08

In the first three of the above four cases the effluents were uniformly non-putrescible, and represented on the average a purification of some 90 per cent. on the crude sewage. They may, therefore, be considered as being ordinary satisfactory sewage effluents. In the case of Berkhamsted the effluent is very variable in quality, being sometimes putrescible.

It should be noted that in none of the cases was a special effluent settling tank provided.

Looked at broadly, the figures show that a variation in quality of about 75 per cent. above and below the mean is a normal feature of a satisfactory or fairly satisfactory sewage effluent. In other words, if the average quality of the effluent be represented by the figure 1·15 for dissolved oxygen absorption in 5 days, then samples giving figures as high as 2·0 and as low as 0·30 will be of comparatively common occurrence.

In order, therefore, to ascertain what we may call the "normal" quality of a given sewage effluent, whether derived from land or from artificial filters, it is essential to adopt some system of sampling which gives a reliable average figure for a particular test.

The details of any system of sampling with a view to determining a trustworthy average must necessarily differ to some extent at different sewage works, and, for this reason, we do not put forward here any particular system as being better than the others.

It may confidently be affirmed, however, as the result of our experience, that no average figures relating to a sewage effluent should be accepted as expressing its "normal" quality unless they are made to cover a period of at least 3 successive months, and have as a basis a plurality—some 12—of chance samples drawn at hours which include the morning, afternoon, evening, and, on occasion, the night.

We may add, further, that, in our opinion, no samples of effluent should be accepted for averaging purpose unless taken after the tanks and filters or land, which constitute the purification process, have been in full use for a period of at least 6 months. Newly-established artificial filters, at any rate, could not safely be taken as mature in a shorter space of time than this. Some exceptions to this rule might be necessary in practice, but they should only be made with the consent of the Central Authority.

If it is desired to ascertain the percentage purification shown by the effluent on the crude sewage, an elaborate system of sampling, according to rate of flow of sewage and effluent, must be adopted for a period of at least 7 consecutive days in dry weather. unless it happens that average figures obtained from a very large number of samples (*e.g.*, daily samples) extending over one or more years are available.

It is clear that systematic sampling for the purpose of ascertaining percentage purification could not habitually be carried out by the River Authority. The work entailed in collecting and analysing such series of samples for each works in a watershed would probably make the task an impracticable one. But, quite apart from this consideration; it would, we think, be undesirable that the River Authority should carry out this systematic sampling on grounds such as follow :—

(1) That it would tend to make Local Authorities dispense with resident or consultative analytical work ; and

(2) That it might, at the same time, put the River Authority in the position of having to advise in detail upon the method of working the purification plants in their watershed.

In our opinion it should be made the duty of every local authority, either alone or in combination with other authorities, to provide such engineering and chemical supervision of its sewage works as would ensure efficient control of the works and the proper recording of the results obtained.

In the event of a Local Authority neglecting to ascertain the percentage purification of sewage habitually attained at its works, it might be made open to the River Authority to take such steps as they deemed fit themselves to obtain the data, and to charge the cost thus incurred to the Local Authority. The analytical data systematically accumulated by local authorities should, we think, be at the service of the Rivers Authority for use in determining the "normal" quality of the sewage or effluent discharge. But a Rivers Authority adopting for averaging purposes data thus provided by a local authority should not be at liberty to select records applying to any period of time less than 6 months. It should be provided, further, that the 6 months so selected should be those which immediately precede the date of drawing the single sample upon which it is proposed to base the prosecution.

The existence of analytical records relating to each particular sewage works would be a safeguard to the local authority against undue pressure by the Rivers Authority, and would thus do away with the main objection to the giving of power to the Rivers Authority to take legal proceedings on the results obtained from a single sample.

Though no Rivers Authority would be likely to rely upon results obtained from a single sample for purposes of prosecution, there are, nevertheless, very strong reasons for allocating such power to the River Authority.

It is almost essential, for instance, that this power should be held by the Rivers Authority, in order to prevent wilful misuse of by-pass valves and overflows ; and it appears to us that in such a case prosecution and conviction to be effective would need to follow the misdemeanour without delay.

In our opinion, the same power should be exercisable in the case of an effluent which has been found persistently to infringe the standard applicable for a particular sewage works.

If the results of analysis of more than one sample had to be adduced in support of legal proceedings, the period of time to be covered by the sampling would have to be specified. If a time limit were specified it might be a simple matter for the offending authority to circumvent the object of the Rivers Authority in the drawing of further samples by diluting their effluent with clean water, or by the temporary use of chemicals too expensive for everyday purposes.

If the Commission recommend that power be reserved to the Rivers Authority to take legal proceedings upon the chemical results obtained with a single sample it will obviously be necessary to take fully into consideration the ways in which this power might be abused, and to frame their recommendations accordingly.

We would suggest, for instance, that the River Authority, while holding the power to prosecute on the results of a single sample, should not in actual practice, except in the case of wilful misdemeanour, take proceedings unless they have satisfied themselves by the chemical analysis (made either by the chemist to the local authority or by themselves) of a number of samples taken over a considerable period of time, that the discharge infringes the standard prescribed, not now and again but frequently and as a natural and inevitable result of the working of the purification plant.

The Commission might, indeed, recommend as a working rule for Rivers Authorities that definite infringement of the standard should not be deemed to have occurred unless out of twelve samples, taken either by the Rivers Authority or the local authority, at least three gave a figure or figures of analysis in excess of the prescribed standard figure or figures.

Some such working rule is, we think, necessary in the case of sewage-derived liquors which are normally subject to considerable variation in quality. It would tend to prevent the River Authority taking undue notice of that occasional infringement of the standard which is certain to take place as matter of accident at every sewage works at times of sudden storms or temporary breakdown of plant or machinery.

The procedure to be adopted in the actual collection of samples must necessarily depend very largely upon local circumstances.

Still, it is important that part at least of the procedure should follow certain lines. For instance, the sample bottles should have well fitting glass stoppers, they should be filled to the exclusion of all air, and when the bottles are filled the stoppers should be bound down with pieces of clean rag.

Again, when once a sample has been drawn it should be packed and despatched without avoidable delay. If some delay is unavoidable, the sample should in the meantime be kept in a moderately warm room until it is despatched.

It is important also, that the sample should be drawn either at the point of actual discharge from the premises comprising the sewage works of the local authority, or at a point to be agreed upon by that authority and the River Authority.

And, finally, it is desirable that the representative of the local authority should be notified either before a sample is to be drawn, or as soon as possible after it is drawn, in order that he may, if he so desires, draw a corresponding sample himself for independent examination.

Another point of importance arises in connection with procedure in dealing with samples antecedent to analysis. It relates more especially to the time which is allowed to elapse between the drawing of the sample and its examination in the laboratory.

All sewage derived liquors are subject to change of composition on keeping, the rate of change depending largely upon the conditions under which the sample is kept. Temperature is perhaps the most important factor in this connection.

Near 0° C. the rate of change is slow, but at ordinary temperatures, say, from 10° to 20° C., it is appreciable with sewage liquors and effluents generally. In the case of highly oxidized effluents, the actual change is so slight as to be almost negligible, but with effluents of only moderate quality it is apt to become marked.

Special experiments with sewage, tank liquors, and various kinds of effluents have been made with the object of studying the effect, as regards the standard tests, of keeping these liquids for different lengths of time. The results are given below:—

EXPERIMENT WITH CRUDE SEWAGE.

A sample of Ealing sewage, drawn on June 9th, 1902, was poured into a pail, large pieces of paper and very coarse solids being removed. While the contents of the pail were being kept constantly stirred, four half-Winchester bottles were filled from it with a beaker.

The stoppered bottles were then allowed to stand in the laboratory for different periods of time before their contents were analysed.

The temperature of the laboratory averaged about 16° to 15° C. at this time.

EALING CRUDE SEWAGE.

Samples made up at 5 p.m., June 9th, 1902. Parts per 100,000.

Number of bottle and date of analysis.	No. 1. Analysed June 10.	No. 2. Analysed June 11.	No. 3. Analysed June 12.	No. 4. Analysed June 16.
Ammoniacal nitrogen	9·98	10·21*	10·68†	11·78‡
Albuminoid nitrogen	1·82	1·79	1·54	0·72
Nitrous nitrogen	none	—	—	—
Nitric nitrogen	—	—	—	—
Total nitrogen (Kjeldahl)	13·56	13·48	13·49	13·57
Organic nitrogen (by difference)	3·68	3·27	2·81	1·79
Oxygen absorbed from $\frac{N}{8}$ permanganate at 80° F.— at once	3·00	3·39	3·93	5·10
Oxygen absorbed from $\frac{N}{8}$ permanganate at 80° F.— in 4 hours	16·87	15·77	15·23	14·53
Chlorine	10·60	10·60	10·54	10·66
Solids in suspension	43·1 28·9 v. 13·2 n.v.	40·3 30·2 v. 10·1 n.v.	40·2 34·1 v. 6·1 n.v.	36·9 29·4 v. 7·5 n.v.
Solids in solution	77·6 27·5 v. 50·1 n.v.	75·4 23·4 v. 52·0 n.v.	73·9 19·3 v. 54·6 n.v.	75·4 26·4 v. 49·0 n.v.
Total solids	119·7 56·4 v. 63·3 n.v.	115·7 53·6 v. 62·1 n.v.	114·1 53·4 v. 60·7 n.v.	112·3 55·8 v. 56·5 n.v.
Remarks	Turbid and brown. Sewage smell. Alkaline.	Same as No. 1	Same as Nos. 1 and 2.	Rather more turbid than preceding samples. Mixtures of H_2S and sewage smell. Alkaline. Appreciable black mud.

* Added 2 drops of sodium carbonate solution containing 27·0 grammes of Na_2CO_3 per litre.
† Added 2 drops of sodium carbonate solution containing 27·0 grammes of Na_2CO_3 per litre.
‡ Added 6 drops of sodium carbonate solution containing 27·0 grammes of Na_2CO_3 per litre.

It will be seen that a slight change of composition had occurred in this sample of sewage by the end of about 40 hours after it was made up, and that in 7 days the composition was materially different. The change is clearly one of degradation, the more complex organic impurities breaking down into simpler substances.

The "5 days'" dissolved oxygen absorption test was not practised at this time. So far as the suspended solids are concerned, and this is the primary test for sewages and sewage liquors, there is no material change in 24 hours or 48 hours.

Experiments with Tank Liquors.

Samples of settled sewage (Uxbridge and South Norwood), septic tank liquor (Wembley), and precipitation liquor (Ealing and Hanwell), were taken each in a large enamelled iron pail. After stirring quietly for 10 minutes*, and while the stirring continued, five small bottles, each holding 600 to 700 cc., were filled from the pail and taken direct to the laboratory.

One sample was analysed 2 hours after collection, three were kept in an incubator at 18° C.† for 24, 48, and 72 hours, respectively, before analysis, while the fifth sample was put in the ice box for 72 hours.

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* Some experiments as to the time necessary to obtain a uniform mixture of the liquid and solid portions of an effluent in a pail by *gentle* stirring were made in December, 1912. They showed that 2 minutes stirring was sufficient; but in order to err on the safe side 3 minutes stirring was allowed for all samples drawn after December 11th, 1912. It was, of course, important for these experiments to oxygenate the samples as little as possible, and we found that 3 minutes *gentle* stirring only had a slight oxygenating effect, even in effluents which contained very little oxygen to begin with.

† It must be pointed out that this temperature more nearly approaches summer conditions than those of winter.

UXBRIDGE.

SETTLED SEWAGE.

	Sample analysed after drawing.*	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
Sample drawn	9.40 a.m. Oct. 9, 1912	9.40 a.m. Oct. 9, 1912	9.40 a.m. Oct. 9, 1912	9·40 a.m. Oct. 9, 1912	9.40 a.m. Oct. 9, 1912
Sample analysed	11.40 a.m. Oct. 9, 1912	11.45 a.m. Oct. 10, 1912	11.45 a.m. Oct. 11, 1912	9.30 a.m. Oct. 12, 1912	9.30 a.m. Oct. 12, 1912
Ammoniacal nitrogen	3·37	3·36	3·65	3·72	3·76
Albuminoid nitrogen	1·38	1·29	1·12	1·24	1·32
Nitrous nitrogen	0·00	0·00	0·00	0·00	0·00
Nitric nitrogen	0·00	0·00	0·00	0·00	0·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	16·21	16·02	16·35	16·19	16·07
Solids in suspension	65·5 45·5 v. 20·0 n.v.	64·5 41·5 v. 23·0 n.v.	61·5 41·5 v. 20·5 n.v.	66·5 43·0 v. 23·5 n.v.	67·5 43·5 v. 24·0 n.v.
Oxygen in solution (when drawn)	0·0	—	—	—	—
,, ,, ,, (when analysed)	—	0·0	—	—	—
Dissolved oxygen taken up in 5 days at 65° F.	39·9	41·0	39·0	38·4	42·3
Remarks	Dark and foul. Much black suspended matter. Strong sewage septic smell. Much H_2S.	Dark and foul. Much black suspended matter. Strong sewage septic smell. Much H_2S.	Dark and foul. Much black suspended matter. Strong sewage septic smell. Much H_2S.	Dark and foul. Much black suspended matter. Strong sewage septic smell. Much H_2S.	Dark and foul. Much black suspended matter. Strong sewage septic smell. Much H_2S.

SOUTH NORWOOD.

SETTLED TANK LIQUOR.

	Sample analysed after drawing. 1*a*.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days. 1*e*.
		24 hours. 1*b*.	48 hours. 1*c*.	72 hours. 1*d*.	
Sample drawn	8·45 a.m. Jan. 1, 1913	8·45 a.m. Jan. 1, 1913	8.45 a.m. Jan. 1, 1913	8.45 a.m. Jan. 1, 1913	8.45 a.m. Jan. 1, 1913
Sample analysed	11.30 a.m. Jan. 1, 1913	11.30 a.m. Jan. 2, 1913	11.30 a.m. Jan. 3, 1913	10.0 a.m. Jan. 4, 1913	10.0 a.m. Jan. 4, 1913
Ammoniacal nitrogen	1·40	1·65	1·95	2·03	1·95
Albuminoid nitrogen	0·33	0·36	0·41	0·50	0·49
Nitrous nitrogen	0·05	0·25	0·02	0·00	0·17
Nitric nitrogen	0·92	0·00	0·00	0·00	0·36
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	5·23	4·53	4·02	4·09	4·42
Solids in suspension	9·8 8·0 v. 1·8 n.v.	10·8 8·0 v. 2·8 n.v.	10·4 7·0 v. 3·4 n.v.	8·6 6·6 v. 2·0 n.v.	11·8 8·2 v. 3·6 n.v.
Oxygen in solution (when drawn)	0·47	—	—	—	—
,, ,, ,, (when analysed)	—	0·00	—	—	—
Dissolved oxygen taken up in 5 days at 65° F.	14·8	13·6	14·5	12·7	14·2
Remarks	Turbid liquor with considerable amount of fine suspended matter. Sewage smell.	Very marked aggregation and settlement of colloidal matter.	Same appearance. Stronger sewage smell.	Darker colour. Putrid.	Solids well coagulated. Fresh smell.

WEMBLEY.

SEPTIC TANK LIQUOR.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
Sample drawn - - - - -	9·10 a.m. Oct. 16, 1912	9.10 a.m. Oct. 16, 1912	9 10 a.m. Oct. 16, 1912	9.10 a.m. Oct. 16, 1912	9.10 a.m. Oct. 16, 1912
Sample analysed - - - - -	11.15 a.m. Oct. 16, 1912	11.15 a.m. Oct. 17, 1912	11.15 a.m. Oct. 18, 1912	9.30 a.m. Oct. 19, 1912	9.30 a.m. Oct. 19, 1912
Ammoniacal nitrogen - - - -	4·57	4·60	4·57	4·56	4·78
Albuminoid nitrogen - - - -	0·68	0·54	0·63	0·65	0·63
Nitrous nitrogen - - - - -	0·00	0·00	0·00	0·00	0·00
Nitric nitrogen - - - - -	0·00	0·00	0·00	0·00	0·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	8·71	8·64	8·97	9·30	8·57
Solids in suspension - - - -	14·4 9·8 v. 4·6 n.v.	16·8 11·6 v. 5·2 n.v.	14·2 9·2 v. 5·0 n.v.	13·4 8·8 v. 4·6 n.v.	14·0 9·2 v. 4·8 n.v.
Oxygen in solution (when drawn) - -	0·0	—	—	—	—
,, ,, (when analysed) -	—	0·0	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	20·4	20·9	18·6	13·6	16·7
Remarks - - - - - - - -	Brownish and turbid. Much fine black suspended matter. Strong septic smell, much H_2S.	Brownish and turbid. Much fine black suspended matter. Strong septic smell, much H_2S.	Brownish and turbid. Much fine black suspended matter. Strong septic smell, much H_2S.	Brownish and turbid. Much fine black suspended matter. Strong septic smell, much H_2S.	Brownish and turbid. Much fine black suspended matter. Strong septic smell, much H_2S.

EALING (NORTHERN WORKS).

PRECIPITATION LIQUOR.

	Sample analysed after drawing. 1*a*	Sample kept in incubator at 18° C. for :—			Sample kept in ice for 3 days. 1*e*.
		24 hours. 1*b*.	48 hours. 1*c*.	72 hours. 1*d*.	
Sample drawn - - - - - -	10.15 a.m. Jan. 1, 1913	10.15 a.m. Jan. 1, 1913	10.15 a.m. Jan. 1, 1913	10.15 a.m. Jan. 1, 1913	10.15 a.m. Jan. 1, 1913
Sample analysed - - - - -	11.30 a.m. Jan. 1, 1913	11.30 a.m. Jan. 2, 1913	11.30 a m Jan. 3, 1913	7.30 a.m. Jan. 4, 1913	7.30 a.m. Jan. 4, 1913
Ammoniacal nitrogen - - - -	3·49	3·69	3·87	4·08	3·64
Albuminoid nitrogen - - - -	0·53	0·54	0·45	0·44	0·48
Nitrous nitrogen - - - - -	0·00	0·00	0·00	0·00	0·00
Nitric nitrogen - - - - -	0·21	0·00	0·00	0·00	0·00
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	5·81	5·30	4·81	4·65	5·21
Solids in suspension - - - -	5·4 4·6 v. 0·8 n.v.	5·0 3·9 v. 1·1 n.v.	5·2 4·4 v. 0·8 n.v.	4·4 3·9 v. 0·5 n.v.	6·1 4·5 k. 1·6 n.v.
Oxygen (when drawn) - - - -	0·22	—	—	—	—
,, (when analysed) - - - -	—	0·00	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - -	14·2	13·2	12·8	12·7	13·5
Remarks - - - - - - -	Brownish and opalescent. Fair amount of very fine suspended matter. Slight sewage smell.	Turned black. H_2S.	Black. H_2S.	Black. H_2S.	Blackened, but not so much as No. 1*d*. H_2S.

HANWELL.

Precipitation Liquor.

	Sample analysed after drawing. 1*a*.	Sample kept in incubator at 18° C. for :—			Sample kept in ice for 3 days. 1*e*.
		24 hours. 1*b*.	48 hours. 1*c*.	72 hours. 1*d*.	
Sample drawn - - - - - -	9.25 a.m. Dec. 11, 1912	9.25 a.m. Dec. 11, 1912	9.25 a.m. Dec. 11, 1912	9.25 a.m. Dec. 11, 1912	9.25 a.m. Dec. 11, 1912
Sample analysed - - - - - -	11.30 a.m. Dec. 11, 1912	11.30 a.m. Dec. 12, 1912	11.30 a.m Dec. 13, 1912	9.30 a.m. Dec. 14, 1912	9.30 a.m. Dec. 14, 1912
Ammoniacal nitrogen - - - - -	1·70	1·67	1·74	1·71	1·62
Albuminoid nitrogen - - - - -	0·24	0·32	0·33	0·29	0·33
Nitrous nitrogen - - - - - -	0·08	0·00	0·00	0·00	0·00
Nitric nitrogen - - - - - -	1·34	0·20	0·15	0·00	0·17
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	3·70	3·10	2·83	2·75	2·78
Solids in suspension - - - - -	4·4 3·4 v. 1·0 n.v.	5·1 4·2 v. 0·9 n.v.	5·6 4·5 v. 1·1 n.v.	3·9 3·5 v. 0·4 n.v.	4·9 4·3 v. 0·6 n.v.
Oxygen (when drawn) - - - - -	0·36	—	—	—	—
,, (when analysed) - - - - -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	9·44	5·20	5·62	5·08	5·26
Remarks - - - - - - - -	Fairly turbid. Moderate amount of fine light coloured suspended matter. Distinct sewage smell.	Slight fishy smell.	Stronger sewage smell.	Much H_2S. Putrid smell.	Slight sewage smell.

HANWELL.

Precipitation Liquor.

	Sample analysed after drawing. 1*a*.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days. 1*e*.
		24 hours. 1*b*.	48 hours. 1*c*.	72 hours. 1*d*.	
Samples drawn - - - - - -	9.5 a.m. Oct. 2, 1912	9.5 a.m. Oct. 2, 1912	9.5 a.m. Oct. 2, 1912	9.5 a.m. Oct. 2, 1912	9.5 a.m. Oct. 2, 1912
Samples analysed - - - - - -	11.0 a.m. Oct. 2, 1912	11.0 a.m. Oct. 3, 1912	11.0 a.m. Oct. 4, 1912	9.30 a.m. Oct. 5, 1912	11.0 a.m. Oct. 5, 1912
Ammoniacal nitrogen - - - - -	1·18	1·16	1·28	1·32	1·20
Albuminoid nitrogen - - - - -	0·28	0·30	0·30	0·27	0·31
Nitrous nitrogen - - - - - -	0·21	0·25	0·00	0·00	0·25
Nitric nitrogen - - - - - -	0·59	0·01	0·09	0·00	0·24
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	2·95	2·99	2·28	2·49	2·89
Solids in suspension - - - - -	3·9 3·1 v. 0·8 n.v.	5·6 4·4 v. 1·2 n.v.	4·7 3·6 v. 1·1 n.v.	5·0 4·1 v. 0·9 n.v.	5·1 4·0 v. 1·1 n.v.
Oxygen in solution (when drawn) - -	0·38	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	7·30	2·90	3·30	3·72	4·50
Remarks - - - - - - - -	Good precipitation liquor. Not very turbid. Very little suspended matter. Tarry smell.	Same appearance and smell as 1*a*.	Suspended solids rather more aggregated than 1*b*. Smell more unpleasant. No H_2S.	Brownish and opalescent. Distinct sewage smell. Distinct H_2S.	Same appearance and smell as 1*a*.

It will be seen from these tables that, although the variations in the figures due to the keeping of the samples are not by any means regular, yet the general tendency is in the same direction. The ammoniacal nitrogen tends to increase at the expense of the organic nitrogen, while the figure for dissolved oxygen absorption in 5 days diminishes. The figures for solids in suspension are, as a rule, not materially affected.*

The following tables show the actual variations in the figures for the two proposed "Standard" tests :—

SEWAGE LIQUORS.

Solids in Suspension. Parts per 100,000.

	Actual variations for samples kept at 18° C. for			Actual variation for samples kept in ice for 72 hours.
	24 hours.	48 hours.	72 hours.	
Settled sewage (Uxbridge)	− 1·0	− 4·0	+ 1·0	+ 2·0
,, ,, (South Norwood)	+ 1·0	+ 0·6	− 1·2	+ 2·0
Septic tank liquor (Wembley)	+ 2·4	− 0·2	− 1·0	− 0·4
Precpiitation liquor (North Ealing)	− 0·4	− 0·2	− 1·0	+ 0·7
,, ,, (Hanwell)	+ 0·7	+ 1·2	− 0·5	+ 0·5
,, ,, (,,)	+ 1·7	+ 0·8	+ 1·1	+ 1·2

SEWAGE LIQUORS.

Dissolved Oxygen Absorption in 5 Days at 65° F. Parts per 100,000.

	Actual variations for samples kept at 18° C. for			Actual variations for samples kept in ice for 72 hours.
	24 hours.	48 hours.	72 hours.	
Settled sewage (Uxbridge)	+ 1·1	− 0·9	− 1·5	+ 2·4
,, ,, (South Norwood)	− 1·2	− 0·3	− 2·1	− 0·6
Septic tank liquor (Wembley)	+ 0·5	− 1·8	− 6·8	− 3·7
Precipitation liquor (North Ealing)	− 1·0	− 1·4	− 1·5	− 0·7
,, ,, (Hanwell)	− 4·2	− 3·8	− 4·3	− 4·2
,, ,, (,,)	− 4·4	− 4·0	− 3·6	− 2·8

It should be noted particularly that the presence of available oxygen, either as free dissolved oxygen or as nitrate or nitrite-oxygen, influences the change of composition very considerably. Such oxygen is rapidly used up, the free oxygen usually disappearing within 24 hours, and the nitrate and nitrite-oxygen within 48 hours.

Comparing the diminution in the figure for the "5 days'" test with the amount of oxygen taken from solution plus that derived from decomposition of nitrates and nitrites, it would seem in some cases that the one may be regarded as accounting for the other, and the rapid change held to be dependent on this.

Probably it is so dependent. In one case, however, there was neither dissolved oxygen nor oxidized nitrogen present, and yet the sample underwent change in the above sense very appreciably. Another sample which contained neither dissolved oxygen nor oxidized nitrogen underwent hardly any change.

The following table brings out these points :—

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* In particular cases, as, for instance, where the tank liquor contained an unusual quantity of iron or where an excess of precipitant was used, the figures would be materially affected.

CALCULATED AND OBSERVED DIMINUTION IN THE FIGURE FOR DISSOLVED OXYGEN ABSORPTION IN 5 DAYS AT 65° F. PARTS PER 100,000.

	Uxbridge settled sewage drawn October 9, 1912.	S. Norwood settled sewage drawn January 1, 1913.	Wembley septic tank liquor drawn October 17, 1912.	N. Ealing precipitation liquor drawn January 1, 1913.	Hanwell precipitation liquor drawn December 11, 1912.	Hanwell precipitation liquor drawn October 2, 1912.	Hanwell precipitation liquor drawn October 2, 1912.
Sample kept at 18° C. for	24 hours.	24 hours.	24 hours.	24 hours.	24 hours.	24 hours.	48 hours.
Diminution or increase in nirite oxygen*	0·00	+ 0·342	0·00	0·00	– 0·137	+ 0·068	– 0·359
Diminution or increase in nitrate oxygen*	0·00	– 2·628	0·00	– 0·600	– 3·257	– 1·617	– 1·428
Diminution in dissolved oxygen	0·00	– 0·47	0·00	– 0·22	– 0·36 †	– 0·38 †	– 0·38
Total diminution in available oxygen	0·00	– 2·756	0·00	– 0·82	– 3·754	– 1·929	– 2·167
Observed diminution or increase in figure for dissolved oxygen absorption in 5 days at 65° F.	+ 1·10	– 1·200	+ 0·50	– 1·00	– 4·24	– 4·40	– 4·00
Remarks	Available oxygen all used up.	Available oxygen not all gone.	Available oxygen all used up.	Available oxygen all used up.	Available oxygen not all gone.	Available oxygen not all gone.	Available oxygen not all gone.

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* NOTE.—In calculating the amount of oxygen derivable from Nitrite + Nitrate, we have assumed that the following equations hold good :—

For Nitrite $2\ N\ O_3 = 2\ N_2 + 3\ O_2$
$= 56 \quad 96$
$= 1 \quad 1{\cdot}71$

For Nitrate $2\ N_2O_5 = 2\ N_2 + 5\ O_2$
$= 56 \quad 160$
$= 1 \quad 2{\cdot}857$

† The dissolved oxygen in the sample kept for 24 hours was not estimated in these cases. There can be no doubt that it had all gone by 24 hours.

So far as suspended solids are concerned, and this is the important test in connection with sewages and tank liquors, it may be noted that the keeping of the samples for periods of 48 or 72 hours did not materially affect their quantity.

The analytical difficulties in the estimation of suspended solids in sewages and tank liquors are themselves such as to account for considerable variations in the observed results, and allowance has to be made for this.

Speaking generally, therefore, the effects of keeping for 1 to 3 days, either at 18° C. or in ice, may practically be discounted as regards sewages and tank liquors, unless we are dealing with a precipitation liquor which contains much iron or aluminium, when the suspended solids are markedly increased by keeping. Still, the changes may be sufficiently great to bring a liquor which was near the Standard figure, as regards suspended solids, when drawn, slightly above that figure when analysed.

EXPERIMENTS WITH EFFLUENTS.

The experiments with effluents were carried out in a manner similar in all respects to that adopted for the experiments with tank liquor. Five small samples were taken from a large pailfull of effluent and analysed at different times. The samples comprised seven percolating filter effluents, three secondary contact bed effluents, and three land (irrigation) effluents.

HANWELL.

PERCOLATING FILTER EFFLUENT.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2a.	*2b.*	*2c.*	*2d.*	*2e.*
Sample drawn - - - - - -	9.40 a.m. Oct. 2, 1912	9.40 a.m. Oct. 2. 1912	9.40 a.m. Oct. 2, 1912	9.40 a.m. Oct. 2, 1912	9.40 a.m. Oct. 2, 1912
Sample analysed - - - - -	11 a.m. Oct. 2, 1912	11 a.m. Oct. 3, 1912.	11 a.m. Oct. 4, 1912	9.30 a.m. Oct. 5, 1912	11 a.m. Oct. 5, 1912
Ammoniacal nitrogen - - - -	0·02	0·01	0·01	0·01	0·01
Albuminoid nitrogen - - -	0·10	0·09	0·09	0·09	0·10
Nitrous nitrogen - - - - - -	trace	0·00	0·00	0·00	0·00
Nitric nitrogen - - - - - -	1·92	1·75	1·90	2·00	1·95
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	0·87	0·83	0·66	0·94	0·74
Solids in suspension - - - -	2·0 1·5 v. 0·5 n.v.	2·4 1·7 v. 0·7 n.v.	2·1 1·6 v. 0·5 n.v.	2·3 1·6 v. 0·7 n.v.	2·7 1·8 v. 0·9 n.v.
Oxygen in solution (when drawn) - -	0·87	—	—	—	—
Oxygen in solution (when analysed) - -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	0·34	0·24	0·26	0·33	0·34
Remarks - - - - - - -	Bright, clear effluent, with a small amount of fine brown solids. Earthy smell.	No change in appearance.	Same appearance as before. Faint earthy smell.	Same appearance.	Same appearance. Earthy smell.

EALING (Northern Works).

Percolating Filter Effluent.

	Sample analysed after drawing.	Sample kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2a.	2b.	2c.	2d.	2e.
Sample drawn	10 a.m. Dec. 11, 1912	10 a.m. Dec. 11, 1912	10 a.m. Dec. 11, 1912.	10 a.m. Dec. 11, 1912	10 a.m. Dec. 11, 1912
Sample analysed	11.30 a.m. Dec. 11, 1912	11.30 a.m. Dec. 12, 1912	11.30 a.m. Dec. 13, 1912	10.30 a.m. Dec. 14, 1912	10.30 a.m. Dec. 14, 1912
Ammoniacal nitrogen	0·03	0·02	0·02	0·02	0·03
Albuminoid nitrogen	0·07	0·06	0·06	0·07	0·07
Nitrous nitrogen	trace	0·02	0·02	0·02	0·01
Nitric nitrogen	3·10	3·48	3·48	3·52	3·39
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	0·87	0·87	0·80	0·94	0·78
Solids in suspension	0·7 0·3 v. 0·4 n.v.	0·8 0·6 v. 0·2 n.v.	1·3 0·8 v. 0·5 n.v.	1·3 0·8 v. 0·5 n.v.	0·9 0·5 v. 0·4 n.v.
Oxygen in solution (when drawn)	0·94	—	—	—	—
„ „ (when analysed)	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F.	0·39	0·54	0·20	0·11	—
Remarks	Bright liquor. Faint brown colour. Trace of suspended matter. No smell.	No smell.	Faint earthy smell.	—	—

HANWELL.

Percolating Filter Effluent.

	Sample analysed after drawing.	Sample kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2a.	2b.	2d.	2c.	2e.
Sample drawn	9.45 a.m. Dec. 11, 1912	9.45 a.m. Dec. 11, 1912	9.45 a.m. Dec. 11, 1912	9.45 a.m. Dec. 11, 1912	9.45 a.m. Dec. 11, 1912
Sample analysed	11.30 a.m. Dec. 11, 1912	11.30 a.m. Dec. 12, 1912	11.30 a.m. Dec. 13, 1912	9.30 a.m. Dec. 14, 1912	9.30 a.m. Dec. 14, 1912
Ammoniacal nitrogen	0·04	0·03	0·02	0·02	0·02
Albuminoid nitrogen	0·09	0·09	0·09	0·09	0·09
Nitrous nitrogen	0·00	0·00	trace to 0·01	0·00	0·00
Nitric nitrogen	3·21	3·40	3·52	3·48	3·60
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·07	1·08	0·86	0·66	0·87
Solids in suspension	1·9 1·1 v. 0·8 n.v.	1·6 1·2 v. 0·4 n.v.	1·8 1·2 v. 0·6 n.v.	1·2 1·0 v. 0·2 n.v.	1·0 0·9 v. 0·1 n.v.
Oxygen in solution (when drawn)	0·92	—	—	—	—
„ „ (when analysed)	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F.	0·45	0·12	0·20	0·25	0·22
Remarks	Slightly brownish, bright and clear. Considerable fine, brownish solids. Very slight earthy smell.	Slight earthy smell.	Slight earthy smell.	Slight earthy smell.	Slight earthy smell.

EALING (NORTHERN WORKS).

PERCOLATING FILTER EFFLUENT.

	Sample analysed after drawing.	Sample kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	3*a*.	3*b*.	3*c*.	3*d*.	3*e*.
Sample drawn - - - - - -	10 a.m. Jan. 1, 1913	10 a.m. Jan. 1, 1913	10 a.m. Jan. 1, 1913	10 a.m. Jan. 1, 1913	10 a.m. Jan. 1, 1913
Sample analysed - - - - -	11.30 a.m. Jan. 1, 1913	11.30 a.m. Jan. 2, 1913	11.30 a.m. Jan. 3, 1913	7.30 a.m. Jan. 4, 1913	7.30 a.m. Jan. 4, 1913
Ammoniacal nitrogen - - - -	0·14	0·12	0·11	0·09	0·12
Albuminoid nitrogen - - - -	0·09	0·09	0·08	0·08	0·08
Nitrous nitrogen - - - - -	0·02	0·03	0·08	0·09	0·01
Nitric nitrogen - - - - -	2·72	2·79	2·62	2·71	2·83
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	1·07	1·02	0·89	0·84	0·95
Solids in suspension - - - -	1·0 0·7 v. 0·3 n.v.	1·0 0·6 v. 0·4 n.v.	0·9 0·3 v. 0·6 n.v.	1·3 0·7 v. 0·6 n.v.	1·1 0·7 v. 0·4 n.v.
Oxygen in solution (when drawn) - -	0·94	—	—	—	—
,, ,, (when analysed) -	—	0·70	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - -	0·73	0·67	0·43	0·65	0·78
Remarks - - - - - - -	Bright and almost clear. Little suspended matter. Slight earthy smell.	Very slight earthy smell.	Slight earthy smell.	Slight earthy smell.	Slight earthy smell.

CARSHALTON.

SETTLED FILTER EFFLUENT.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2*a*.	2*b*.	2*c*.	2*d*.	2*e*.
Sample drawn - - - - - -	8.30 a.m. Oct. 30, 1912	8.30 a.m. Oct. 30, 1912	8.30 a.m. Oct. 30, 1912	8.30 a.m. Oct. 30, 1912	8.30 a.m. Oct. 30, 1912
Sample analysed - - - - -	11.0 a.m. Oct. 30, 1912	11.0 a.m. Oct. 31, 1912	11.0 a.m. Nov. 1, 1912	11.0 a.m. Nov. 2, 1912	11.0 a.m. Nov. 2, 1912
Ammoniacal nitrogen - - - -	0·27	0·23	0·18	0·22	0·21
Albuminoid nitrogen - - - -	0·16	0·15	0·14	0·15	0·16
Nitrous nitrogen - - - - -	0·03	0·05	0·07	0·06	0·07
Nitric nitrogen - - - - -	2·37	2·45	2·53	2·78	2·65
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	1·75	1·72	1·68	1·66	1·75
Solids in suspension - - - -	3·2 2·2 v. 1·0 n.v.	2·5 1·9 v. 0·6 n.v.	2·5 1·7 v. 0·8 n.v.	3·0 2·4 v. 0·6 n.v.	3·1 2·5 v. 0·6 n.v
Oxygen in solution (when drawn) - -	0·60	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - -	2·29	1·85	1·50	1·44	1·65
Remarks - - - - - - -	Opalescent with moderate amount of well defined solid. Soapy smell.	Same appearance. Soapy—earthy smell.	Distinctly clearer. Solids fermenting. Earthy smell.	Clearer still. Strong earthy smell.	—

CARSHALTON.

UNSETTLED FILTER EFFLUENT.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	1*a*.	1*b*.	1*c*.	1*d*.	1*e*.
Sample drawn - - - - - -	8.45 a.m. Oct. 30, 1912	8.45 a.m. Oct. 30, 1912	8.45 a.m. Oct. 30, 1912	8.45 a.m. Oct. 30, 1912	Lost.
Sample analysed - - - - - -	11.0 a.m. Oct. 30, 1912	11.0 a.m. Oct. 31, 1912	11.0 a.m. Nov. 1, 1912	11.0 a.m. Nov. 2, 1912	
Ammoniacal nitrogen - - - -	0·26	0·22	0·17	0·19	—
Albuminoid nitrogen - - - -	0·27	0·28	0·30	0·28	—
Nitrous nitrogen - - - - -	0·02	0·09	0·13	0·16	—
Nitric nitrogen - - - - -	2·28	2·31	2·59	2·28	—
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	3·41	3·37	3·23	3·30	—
Solids in suspension - - - -	8·1 5·5 v. 2·6 n.v.	8·3 6·1 v. 2·2 n.v.	8·6 5·8 v. 2·8 n.v.	8·5 5·9 v. 2·6 n.v.	— — —
Oxygen in solution (when drawn) - -	0·69	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	3·10	2·63	2·43	2·30	—
Remarks - - - - - - -	Rather turbid with much well defined brown suspended matter. Earthy smell.	Same appearance.	Rather clearer. Suspended solids fermenting.	Still clearer, Strong earthy smell.	— — —

UXBRIDGE.

FILTER EFFLUENT AT OUTLET.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2*a*.	2*b*.	2*c*.	2*d*.	2*e*.
Sample drawn - - - - - -	9.45 a.m. Oct. 9, 1912	9.45 a.m. Oct. 9, 1912	9.45 a.m. Oct. 9, 1912	9.45 a.m. Oct. 9, 1912	9.45 a.m. Oct. 9, 1912
Sample analysed - - - - - -	12 noon Oct. 9, 1912	11.45 a.m. Oct. 10, 1912	11.45 a.m. Oct. 11, 1912	9.30 a.m. Oct. 12, 1912	9.30 a.m. Oct. 12, 1912
Ammoniacal nitrogen - - - -	1·40	1·35	1·37	1·37	1·40
Albuminoid nitrogen - - - -	0·24	0·24	0·24	0·23	0·22
Nitrous nitrogen - - - - -	0·04	0·13	0·34	0·28	0·05
Nitric nitrogen - - - - -	1·83	1·71	1·44	1·36	1·79
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	2·33	2·31	2·47	2·16	2·02
Solids in suspension - - - -	4·4 3·3 v. 1·1 n.v.	4·3 2·3 v. 2·0 n.v.	5·6 3·9 v. 1·7 n.v.	4·6 3·3 v. 1·3 n.v.	5·8 4·2 v. 1·6 n.v.
Oxygen in solution (when drawn) - -	0·55	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	3·44	2·94	2·35	2·45	2·68
Remarks - - - - - - -	Brownish and slightly opalescent with considerable fine brown solids. Strong fishy tri-methyl-amine smell.	Brownish and slightly opalescent with considerable fine brown solids. Strong fishy tri-methyl-amine smell.	Brownish and slightly opalescent with considerable fine brown solids. Strong fishy tri-methyl-amine smell.	Brownish and slightly opalescent with considerable fine brown solids. Strong fishy tri-methyl-amine smell.	Brownish and slightly opalescent with considerable fine brown solids. Strong fishy tri-methyl-amine smell.

EALING (NORTHERN WORKS).

SECONDARY CONTACT BED EFFLUENT.

	Sample analysed after drawing.	Sample kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours,	72 hours.	
	1a.	1b.	1c.	1d.	1e.
Sample drawn - - - - - - -	9.30 a.m. Dec. 11, 1912	9.30 a.m. Dec. 11, 1912	9.30 a.m. Dec. 11, 1912	9.30 a.m. Dec. 11, 1912	9.30 a.m. Dec. 11, 1912
Sample analysed - - - - - -	11.30 a.m. Dec. 11, 1912	11.30 a.m. Dec. 12, 1912	11.30 a.m. Dec. 13, 1912	10.30 a.m. Dec. 14, 1912	10.30 a.m. Dec. 14, 1912
Ammoniacal nitrogen - - - - -	0·41	0·37	0·37	0·37	0·38
Albuminoid nitrogen - - - - -	0·11	0·09	0·09	0·08	0·10
Nitrous nitrogen - - - - - -	0·02	0·04	0·04	0·04	0·04
Nitric nitrogen - - - - - -	1·08	1·04	1·06	1·16	1·11
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	1·11	0·87	1·07	0·52	0·87
Solids in suspension - - - - -	1·3 0·9 v. 0·4 n.v.	1·6 0·7 v. 0·9 n.v.	1·7 0·9 v. 0·8 n.v.	1·4 0·8 v. 0·6 n.v.	1·4 0·9 v. 0·5 n.v.
Oxygen in solution (when drawn) - -	0·40	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	0·78	0·69	0·55	0·39	0·61
Remarks - - - - - - - -	Opalescent brownish. Practically no suspended matter. Faint earthy smell.	Faint earthy smell.	Earthy smell.	—	Same as 1a.

HARROW.

SECOND CONTACT EFFLUENT.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2a.	2b.	2c.	2d.	2e.
Sample drawn - - - - - - -	In six equal parts—7 a.m.to 9 a.m., October 23, 1912. Sewage from 3 p.m. to 9 p.m. on 22nd.				
Sample analysed - - - - - -	11.0 a.m. Oct. 23, 1912	11.0 a.m. Oct. 24, 1912	11.0 a.m. Oct. 25, 1912	11.0 a.m. Oct. 26, 1912	11.0 a.m. Oct. 26, 1912
Ammoniacal nitrogen - - - - -	0·26	0·22	0·21	0·20	0·25
Albuminoid nitrogen - - - - -	0·16	0·16	0·16	0·16	0·18
Nitrous nitrogen - - - - - -	0·00	0·17	0·00	0·00	0·18
Nitric nitrogen - - - - - -	0·45	0·02	0·00	0·00	0·05
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	1·90	2·02	2·09	1·48	2·22
Solids in suspension - - - - -	3·2 2·5 v. 0·7 n.v.	3·5 2·2 v. 1·3 n.v.	5·0 3·6 v. 1·4 n.v.	4·4 3·0 v. 1·4 n.v.	4·5 3·2 v. 1·3 n.v.
Oxygen in solution (when drawn) - -	0·25	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	3·12	2·89	2·50	2·42	2·89
Remarks - - - - - - - -	Turbid brownish liquor. Small amount of suspended matter. Earthy smell.	Same as 2a. Earthy smell.	No change. Fishy, earthy smell.	Same appearance as 2a. Unpleasant sewage smell.	—

EALING (NORTHERN WORKS).

CONTACT EFFLUENT.

	Sample analysed after drawing. 2*a*.	Sample kept in incubator at 18° C. for :— 24 hours. 2*b*.	48 hours. 2*c*.	72 hours. 2*d*.	Sample kept in ice for 3 days. 2*e*.
Sample drawn	9.45 a.m. Jan. 1, 1913	9.45 a.m. Jan. 1, 1913	9.45 a.m. Jan. 1, 1913	9.45 a.m. Jan. 1, 1913	9.45 a.m. Jan. 1, 1913
Sample analysed	11.30 a.m. Jan. 1, 1913	11.30 a.m. Jan. 2, 1913	11.30 a.m. Jan. 3, 1913	7.30 a.m. Jan. 4, 1913	7.30 a.m. Jan. 4, 1913
Ammoniacal nitrogen	1·66	1·63	1·58	1·66	1·66
Albuminoid nitrogen	0·27	0·24	0·22	0·24	0·22
Nitrous nitrogen	0·03	0·10	0·00	0·00	0·25
Nitric nitrogen	0·61	0·28	0·00	0·00	0·10
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·91	2·23	1·85	1·89	1·99
Solids in suspension	2·8 2·4 v. 0·4 n.v.	2·8 2·0 v. 0·8 n.v.	2·6 2·2 v. 0·4 n.v.	3·3 2·4 v. 0·9 n.v.	2·7 1·9 v. 0·8 n.v.
Oxygen in solution (when drawn)	0·25	—	—	—	—
,, ,, (when analysed)	—	0·00	—	—	—
Dissolved oxygen taken up in 5 days at 65° F.	3·77	2·61	2·57	2·24	2·73
Remarks	Brownish and fairly opalescent. Trace of suspended matter. Strong trimethylamine smell.	Strong trimethylamine smell.	Strong trimethylamine smell.	Strong trimethylamine smell.	Moderate trimethylamine smell.

SOUTH NORWOOD.

FINAL LAND EFFLUENT.

	Sample analysed after drawing. 2*a*.	Sample kept in incubator at 18° C. for :— 24 hours. 2*b*.	48 hours. 2*c*.	72 hours. 2*d*.	Sample kept in ice for 3 days. 2*e*.
Sample drawn	9.15 a.m. Jan. 1, 1913	9.15 a.m. Jan. 1, 1913	9.15 a.m. Jan. 1, 1913	9.15 a.m. Jan. 1, 1913	9.15 a.m. Jan. 1, 1913
Sample analysed	11.30 a.m. Jan. 1, 1913	11.30 a.m. Jan. 2, 1913	11.30 a.m. Jan. 3, 1913	10 a.m. Jan. 4, 1913	10 a.m. Jan. 4, 1913
Ammoniacal nitrogen	0·98	1·00	1·07	1·10	1·05
Albuminoid nitrogen	0·18	0·14	0·16	0·15	0·13
Nitrous nitrogen	0·02	0·03	0·03	0·03	0·02
Nitric nitrogen	0·44	0·42	0·37	0·36	0·41
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	1·38	1·38	1·07	1·14	1·05
Solids in suspension	0·9 0·7 v. 0·2 n.v.	1·3 0·9 v. 0·4 n.v.	1·0 0·9 v. 0·1 n.v.	1·0 0·5 v. 0·5 n.v.	0·7 0·4 v. 0·3 n.v.
Oxygen in solution (when drawn)	0·67	—	—	—	—
,, ,, (when analysed)	—	0·35	—	—	—
Dissolved oxygen taken up in 5 days at 65° F.	1·23	0·98	1·23	2·03	0·47
Remarks	Opalescent with small amount of fine brown solid. Earthy smell.	No change.	No change.	Same appearance. Strong earthy smell.	Same appearance. Earthy smell.

HARROW.

LAND EFFLUENT.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	1*a*.	1*b*.	1*c*.	1*d*.	1*e*.
Sample drawn - - - - - -	9.10 a.m. Oct. 23, 1912	9.10 a.m. Oct. 23, 1912	9.10 a.m. Oct. 23, 1912	9.10 a.m. Oct. 23, 1912	9.10 a.m. Oct. 23, 1912
Sample analysed - - - - - -	11 a.m. Oct. 23, 1912	11 a.m. Oct. 24, 1912	11 a.m. Oct. 25, 1912	11 a.m. Oct. 26, 1912	11 a.m. Oct. 26, 1912
Ammoniacal nitrogen - - - -	0·61	0·58	0·58	0·55	0·64
Albuminoid nitrogen - - - -	0·15	0·15	0·15	0·15	0·12
Nitrous nitrogen - - - - -	0·00	0·00	0·10	0·12	0·00
Nitric nitrogen - - - - -	0·47	0·28	0·10	0·04	0·28
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	0·41	1·18	1·14	1·35	1·61
Solids in suspension - - - -	1·6 1·1 v. 0·5 n.v.	1·9 0·9 v. 1·0 n.v.	2·6 1·7 v. 0·9 n.v.	2·9 1·8 v. 1·1 n.v.	2·2 1·3 v. 0·9 n.v
Oxygen in solution (when drawn) - -	0·65	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	1·78	1·58	1·33	1·03	1·36
Remarks - - - - - - -	Turbid and brownish. Small amount of very fine suspended matter. Earthy smell.	Same appearance as 1*a*. Fishy, earthy smell.	Rather less turbid than 1*b*. Fishy, earthy smell.	Somewhat clearer than 1*a*. Strong, unpleasant, sewage smell.	—

WEMBLEY.

LAND EFFLUENT.

	Sample analysed after drawing.	Samples kept in incubator at 18° C. for :—			Sample kept in ice for 3 days.
		24 hours.	48 hours.	72 hours.	
	2*a*.	2*b*.	2*c*.	2*d*.	2*e*.
Sample drawn - - - - - -	9.45 a.m. Oct. 16, 1912	9.45 a.m. Oct. 16, 1912	9.45 a.m. Oct. 16, 1912	9.45 a.m. Oct. 16, 1912	9.45 a.m. Oct. 16, 1912
Sample analysed - - - - - -	11.15 a.m. Oct. 16, 1912	11.15 a.m. Oct. 17, 1912	11.15 a.m. Oct. 18, 1912	9.30 a.m. Oct. 19, 1912	9.30 a.m. Oct. 19, 1912
Ammoniacal nitrogen - - - -	2·12	2·11	2·14	2·16	2·15
Albuminoid nitrogen - - - -	0·18	0·15	0·15	0·15	0·14
Nitrous nitrogen - - - - -	0·02	0·03	0·02	0·05	0·02
Nitric nitrogen - - - - -	0·55	0·50	0·52	0·48	0·51
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - -	1·54	1·45	1·60	1·33	1·43
Solids in suspension - - - -	0·9 0·2 v. 0·7 n.v.	0·9 0·4 v. 0·5 n.v.	0·9 0·4 v. 0·5 n.v.	1·2 0·4 v. 0·8 n.v.	1·1 0·5 v. 0·6 n.v.
Oxygen in solution (when drawn) - -	0·83	—	—	—	—
,, ,, (when analysed) -	—	—	—	—	—
Dissolved oxygen taken up in 5 days at 65° F. - - - - - - - -	0·68	1·59	2·14	3·01	0·96
Remarks - - - - - - -	Brownish and slightly opalescent. Little fine suspended matter. Distinct fishy smell.	Brownish and slightly opalescent. Little fine suspended matter. Earthy smell.	Brownish and slightly opalescent. Little fine suspended matter. Earthy smell.	Brownish and slightly opalescent. Little fine suspended matter. Earthy smell.	Brownish and slightly opalescent. Little fine suspended matter. Earthy smell.

The figures relating to the last of these samples, drawn at Wembley on October 16th, 1912, stand by themselves, and they will, therefore, be dealt with separately. The behaviour of the other twelve effluents is so far similar that they may be considered together.

Taking these effluents first, we note that, with very few exceptions, certain marked changes resulting from the storage whether at 18° C. or 0° C. are common to all. They are :—

(1) The dissolved oxygen content of the effluent is diminished.

(2) The "5 days" absorption of oxygen is diminished.

(3) The suspended solids increase.

(4) The ammoniacal nitrogen is slightly diminished.

(5) The absorption of oxygen from permanganate in 4 hours is diminished.

It is interesting also to mark how the nitric nitrogen diminishes when it is in comparatively small proportion to the unoxidized nitrogen, but increases when it is in large proportion.

But we are concerned here with samples drawn for submission to the proposed Standard Tests, and need, therefore, only take account of those changes so far as they affect the 5 days' dissolved oxygen absorption and the suspended solids.

The following tables show the variations in the analytical figures of the two "Standard Tests."

EFFLUENTS.

SOLIDS IN SUSPENSION. PARTS PER 100,000.

	Actual variations of figures for samples kept at 18° C. for :—			Actual variations for figures for samples kept in ice for 72 hours.
	24 hours.	48 hours.	72 hours.	
Percolating filter effluent (Hanwell)	+ 0·4	+ 0·1	+ 0·3	+ 0·7
,, ,, ,, (Ealing)	+ 0·1	+ 0·6	+ 0·6	+ 0·2
,, ,, ,, (Hanwell)	– 0·3	– 0·1	– 0·7	– 0·9
,, ,, ,, (Ealing)	0·0	– 0·1	+ 0·3	+ 0·1
,, ,, ,, (Carshalton)	– 0·7	– 0·7	– 0·2	– 0·1
,, ,, ,, ,,	+ 0·2	+ 0·5	+ 0·4	
,, ,, ,, (Uxbridge)	– 0·1	+ 1·2	+ 0·2	+ 1·4
Second contact bed effluent (Ealing)	+ 0·3	+ 0·4	+ 0·1	+ 0·1
,, ,, ,, (Harrow)	+ 0·3	+ 1·8	+ 1·2	+ 1·3
,, ,, ,, (Ealing)	0·0	– 0·2	+ 0·5	– 0·1
Land effluent (South Norwood)	+ 0·4	+ 0·1	+ 0·1	– 0 2
,, ,, (Harrow)	+ 0·3	+ 1·0	+ 1·3	+ 0·6
,, ,, (Wembley)	0·0	0·0	+ 0·3	+ 0·2
Average increase in suspended solid figure	0·07	0·35	0·33	0·25
The average quantity of suspended solids present was 2·46 parts per 100,000, the range being 0·7 to 8·1 parts. The average percentage increase calculated on this figure of 2·46 was	2·8%	14·2%	13·4%	10·2%

EFFLUENTS.

DISSOLVED OXYGEN TAKEN UP IN 5 DAYS AT 65° F. PARTS PER 100,000.

	Actual variations of figures for samples kept at 18° C. for :—			Actual variations for figures for samples kept in ice for 72 hours.
	24 hours.	48 hours.	72 hours.	
Percolating filter effluent (Hanwell)	– 0·10	– 0·08	– 0·01	0·00
,, ,, ,, (Ealing)	+ 0·15	– 0·19	– 0·28	
,, ,, ,, (Hanwell)	– 0·33	– 0·25	– 0·20	– 0·23
,, ,, ,, (Ealing)	– 0·06	– 0·30	– 0·08	+ 0·05
,, ,, ,, (Carshalton)	– 0·44	– 0·79	– 0·85	– 0·64
,, ,, ,, ,,	– 0·47	– 0·67	– 0·80	
,, ,, ,, (Uxbridge)	– 0·50	– 1·09	– 0·99	– 0·76
Second bed contact effluent (Ealing)	– 0·09	– 0·23	– 0·39	– 0·17
,, ,, ,, (Harrow)	– 0·23	– 0·62	– 0·70	– 0·23
,, ,, ,, (Ealing)	– 1·16	– 1·20	– 1·53	– 1·04
Land effluent (South Norwood)	– 0·25	0·00	+ 0·80	– 0·76
,, ,, irrigation (Harrow)	– 0·20	– 0·45	– 0·75	– 0·42
,, ,, ,, (Wembley)	+ 0·91	+ 1·46	+ 2·33	+ 0·28
Average diminution in "5 days" figure	– 0·21	– 0·34	– 0·27	– 0·36
Average diminution in "5 days" figure excluding Wembley	– 0·31	– 0·49	– 0·48	– 0·42
The average "5 day" figure for the first twelve of the above effluents was 1·87, the range being 0·34 to 3·77. The average percentage diminution on this figure of 1·87 was	16·6%	26·2%	25·6%	22·5%

In considering the figures given in these tables it has to be borne in mind that very small quantities of suspended solids and of oxygen are in question, and, notwithstanding all care, errors in sampling and sub-sampling are inevitable.

Nevertheless, the comparatively even tendency of the figures is very striking.

In the case of each test it would appear that with effluents generally, except those of very high quality, an appreciable deposition of suspended solids takes place in a short time, and that with most effluents diminution of oxygen absorbing power occurs within the first 48 hours.

Further, that in the additional interval between 48 and 72 hours the effluent is subject to change in these particulars at a much slower rate.

That this somewhat rapid change is due mainly to the oxidation of the organic matter in the effluent by the oxygen which it contains in solution along with that derived from nitrate and nitrite is strongly indicated; for, when this available oxygen is exhausted, usually after a lapse of about 48 hours, the rate of change diminishes considerably.

The following table brings out these points clearly:—

CALCULATED AND OBSERVED DIMINUTION IN THE FIGURE FOR DISSOLVED OXYGEN ABSORPTION IN 5 DAYS AT 65° F. PARTS PER 100,000.

	N. Ealing percolating filter effluent drawn January 1, 1913.	N. Ealing 2nd contact bed effluent drawn January 1, 1913.	N. Ealing 2nd contact bed effluent drawn January 1, 1913.	N. Ealing 2nd contact bed effluent drawn January 1, 1913.	S. Norwood land effluent drawn January 1, 1913.
Sample kept at 18° C. for - - -	24 hours.	24 hours.	48 hours.	72 hours.	24 hours.
Diminution or increase in nitrite oxygen*	+ 0·017	+ 0·12	– 0·051	– 0·051	+ 0·017
,, ,, ,, nitrate ,, *	+ 0·20	– 0·943	– 1·743	– 1·743	– 0·057
Diminution in dissolved oxygen - -	– 0·24	– 0·25	– 0·25	– 0·25	– 0·32
Total diminution or increase in available oxygen - - - - - - -	+ 0·023	– 1·073	– 2·044	– 2·044	– 0·36
Observed diminution in figure for dissolved oxygen absorption in 5 days at 65° F. -	0·06	1·16	1·20	1·53	0·25
Remarks: - - - - -	Available oxygen not all gone.	Available oxygen not all gone.	Available oxygen all used up.	Available oxygen all used up.	Available oxygen not all gone.

* *See* note to tank liquors.

The Wembley land effluent, drawn on October 16th, 1912, showed the normal tendency to throw out suspended matter, but was consistently peculiar in other respects.

The nitrate oxygen, although present in small proportion to the unoxidized nitrogen, did not diminish, practically, even after 3 days at 18° C., and concurrently with this the absorption of oxygen in 5 days steadily increased.

It seems clear that some agent, inhibitory to the action of bacteria, was present in this effluent, and, it may be added, that there are grounds for believing that chloride of lime is discharged at times into the Wembley sewers.

SUMMARY.

The main point to be noted in the results of these experiments with effluents is that if the proposed "Standard tests" were carried out on a given effluent, say, 12 hours and again 36 hours after the sample was drawn, the results obtained might differ materially as regards compliance with the standards. It is thus desirable that some precise rules should be laid down as to the time which is allowed to elapse between the drawing and the analysis of the sample. The ideal plan for dealing with samples would be to analyse them immediately they were drawn; in the condition, that is, in which they enter the stream. But obviously it would be impossible, save in exceptional instances, for a Rivers Board or a Central Authority uniformly to commence the examination of samples within an hour or two of the time of drawing. It might be possible to begin the analysis in the case of a very large proportion of samples within, say, 24 hours of the time of drawing. But this procedure would have serious drawbacks. Thus, on most days of the week some samples would be examined within a few, others not until after many, hours from the time of drawing, while samples delivered at the laboratory at mid-day on Saturday would remain undealt with for a further period much exceeding 24 hours.

Apart, therefore, from ice packing for transit (which we think would be impracticable), it is virtually impossible to examine under approximately equal conditions all effluents within some 24 hours of drawing. There must necessarily be some delay in nearly every case, and from this point of view delay in all cases for 48 hours (from time of drawing) should go far to render conditions even. In our opinion, indeed, the facts we have recorded above point clearly to the desirablity of delaying the examination up to 48 hours from time of drawing, not only for effluents, but for sewages and tank liquors, provided always that the sample in each instance is kept as nearly as possible at 18° C. from the moment of reception in the laboratory until the expiration of 48 hours from the time of collection. Those samples, which, owing to laboratory routine or the intervention of Sunday, cannot be analysed at the expiration of their 48 hours would then be placed in ice for as short a time as possible.

As to the effect of a 48 hours rule of the above sort in favouring or in penalising samples, it may be observed that the effluents which would gain (as regards coming within the 5 day's Standard test) by being kept for 48 hours at 18° C. (plus an additional 24 or 48 hours in ice, if necessary) would be those giving a figure at discharge of between 2·0 and 3·0, or perhaps 2·0 and 2·5. During the 48 hours of storage in a bottle these would probably absorb their dissolved oxygen, and they might also use up part or all of their nitrate and nitrite oxygen. As this absorption of nitrate—and nitrite—oxygen would not take place so rapidly in a stream so long as dissolved oxygen was available, such an effluent would be judged rather leniently. On the other hand, the plan makes the suspended solid standard a rather more stringent one. It would penalise effluents which contained nearly 3·0 parts of solid matter in suspension as discharged, especially if they were not very well purified.

As the rate of change of composition of an effluent slows down very much after about 48 hours, practical considerations may determine the *outside limit* of time which is to be allowed to elapse between the drawing and the analysis of a sample.

On this point we take a working day of 7 hours (from 10 a.m. to 5 p.m.), with Saturday, 10 a.m. to 1 p.m., and allow for a period of 3 hours as possibly necessary for the filtration stage of the suspended solids test.

Assuming, further, that it is imperative that no hours of the day or night should be cut off from the inspecting authority, we then calculate that the longest period of time required would be from just after 10 a.m. on Saturday morning to 10 a.m. on Wednesday morning, a period of 96 hours.

This might be taken as the outside limit of time.

It would, we think, be advisable to stipulate that after the first 48 hours had elapsed, the sample should be placed in an ice box and kept there until the analysis was begun.

The following table will serve to indicate practical procedure with samples if the above suggestions were to be adopted.

Sample drawn.	Time occupied in transit to the laboratory (say)	Sample at 18° C. in constant temperature room at laboratory for	Sample in ice for	Analysis begun.
Monday, 10 a.m.	3 hours	45 hours	—	10 a.m. Wednesday
Tuesday, 1 a.m.	13 hours	35 hours	9 hours (1 a.m. to 10 a.m. Thursday)	10 a.m. Thursday.
Wednesday, 4 p.m.	2 hours	46 hours	16 hours (6 p.m. Friday to 10 a.m. Saturday)	10 a.m. Saturday
Thursday, 12 noon	10 hours	38 hours	34 hours (12 noon Saturday to 10 a.m. Monday)	10 a.m. Monday
Friday, 8 p.m.	16 hours	32 hours	14 hours (8 p.m. Sunday to 10 a.m. Monday)	10 a.m. Monday
Saturday, 2 p.m.	43 hours	5 hours	44 hours (2 p.m. Monday to 10 a.m. Wednesday)	10 a.m. Wednesday
,, 5 p.m.	41 hours	7 hours	41 hours (5 p.m. Monday to 10 a.m. Wednesday)	10 a.m. Wednesday
Sunday, 11 a.m.	12 hours	36 hours	23 hours (11 a.m. Tuesday to 10 a.m. Wednesday)	10 a.m. Wednesday

The sixth instance in the above imaginary time-table would constitute an extreme case. In practice, Saturday and Sunday samples would probably only be taken on rare occasions, and without this the procedure for the whole week would be fairly uniform and simple.

It is assumed that there is a caretaker at the laboratory whose business it is to remove special samples from the constant temperature room or incubator to the ice box.

The period of time which elapsed between the drawing and analysis of the effluent samples—333 in number—dealt with by us during these stream observations averaged 57 hours, the range being from 17 to 188 hours. The first 24 hours (range 17 to 118 hours) of this 57 hours was *on the average* taken up in transit.

For the remainder of the time, *i.e.*, for 33 hours *on the average* (range from 0 to 168 hours) the sample was in the ice box.

SECTION 10.

THE POSITION OF SEWAGE OR EFFLUENT OUTFALLS IN RIVERS.

Although the question of the position of the outfall has only an indirect bearing upon standards of purity for sewage liquors and sewage effluents, it may be useful to allude to one or two points which arise in this connection.

The observations show that, in the majority of cases, no matter what the dilution may be, pollution is rendered visible to the eye, either through the development of grey algal growth below the outfall, or through the formation of a local deposit of mud.

They show, further, that the extent of the development of grey algæ depends upon the degree of dilution of the sewage liquid, and upon the presence of suitable anchorage.

The point at which the full dilution in a given stream is reached, however, must necessarily be largely influenced by the rapidity and direction of the local current.

The most suitable anchorage for algæ (twigs, grass, etc.), is to be found mainly at the sides of the stream.

It follows, therefore, that in order to minimise the growth of fungus, the sewage liquids should be discharged at a point where the local current velocity of the stream is high, and also, so far as is compatible with high current velocity, in mid stream.

It is certain, for instance, that in cases like those of Middleton-in-Teesdale, Tiverton, and Consett, no sensible quantities of fungus would be visible if the outfalls were placed in the centres of the rapid rivers which receive the sewage liquors at those places.

At Huntingdon, where the outfall is at the side of the river, fungus is seen along the river bank, but at St. Neots, where the outfall is in mid-stream, fungus is very difficult to find. Formerly, when the outfall was at the side of the river, objectionable conditions did exist at St. Neots.

As regards the deposition of mud, similar arguments might be put forward, for this also depends upon the local current velocity of the stream, and the absence or presence of eddies set up by the river bed, and not solely upon the quantity of suspended matter contained in the sewage liquor.

The chief objection to a submerged outfall, whether in mid stream or not, is that it renders sampling at the actual point of discharge practically impossible. This disadvantage could, however, be met by making it compulsory to provide a sampling chamber as near to the point of outfall as levels and other circumstances would allow. (*Cf.* Section 4, page 116.)

SECTION 11.

METHODS OF GAUGING EMPLOYED IN ASCERTAINING FLOW OF RIVERS AND STREAMS.

In order to arrive at the flow of a particular river or stream, by means of floats or current meter, two things must be known :—

(1) The cross sectional area (usually stated in square feet) at a particular point.

(2) The mean velocity of the river or stream at that point. (Usually stated in feet per minute.)

These two being known, their product gives the rate of flow in cubic feet per minute, and this figure multiplied by 9,000 gives the rate of flow in gallons per 24 hours.

There is not, as a rule, much difficulty in obtaining the cross sectional area; there is often very considerable difficulty in obtaining the mean velocity which is almost invariably changing from time to time at a given point.

The mean velocity may be described as being the mean of a number of velocities taken (generally at ·6 the depth of the river) at several verticals throughout the cross section.

If these several vertical velocities remained constant, there would not be much difficulty in obtaining the correct mean velocity at each point, but they are constantly changing (although the stage—*i.e.*, height—of river and the *average* velocity of the whole cross section remain the same) under the influence of pulsations,* the origin of which is so far obscure.

Thus, assuming the velocities at three consecutive verticals to be 3, 4 and 5 feet per second respectively, a minute later they may have altered to 3, 5 and 4 feet per second. This is a matter of some considerable import when floats are used for obtaining the velocity, since the run of the floats may be timed during maximum impulse, in which case the result will be in excess of the true volume, or, on the other hand, if the floats are put in during minimum impulses, the reverse will be the case.

One of the chief advantages of the use of the current meter for gauging purposes is that it gives the average of all the impulses during the count.

Another advantage is, that with the current meter, only one cross section is needed, the meter giving the velocity of the body of water at the instant of passing that cross section. With a float—since the mean velocity is taken over a measured distance, the *mean* cross section for that distance must be known, and therefore two or more cross sections are needed.

There are very many ways of obtaining—(or attempting to obtain)—the velocity of rivers and streams, and they may be roughly divided into: (1) direct; and (2) indirect methods.

By a direct method is meant one by which the velocity is directly obtained from the time taken by a float to traverse a measured distance; by an indirect method is meant measurement of the velocity by a current meter, pitot tube, etc.

In carrying out the gaugings for the Commission, four principal methods of gauging were employed, viz. :—

(1) Cross section and current meter.
(2) Cross sections and floats.
(3) Temporary dam and rectangular weirs.
(4) Measurement of flow over weirs.

The current meter employed was that known as the small Price electric current meter, manufactured by Messrs. W. & L. E. Gurley, of Troy, N.Y. This particular meter possesses many advantages, chief of which is the fact that it is unnecessary to lift it from the water to record a reading, the revolutions being electrically recorded at the surface by a " click " diaphragm. This meter was rated several times throughout the observations, and found to be very accurate. It was, however, deemed inadvisable to employ a current meter for lower velocities than ·5 foot per second.* When it was impossible to use floats, by reason of weeds, etc., and the velocity at the usual cross section was too low to admit of the use of the meter, a fresh section was taken where the area of cross section was smaller, and the velocity consequently greater.

When the velocity of the river or stream near the banks (*i.e.*, in the slowest portion of the stream) was less than about ·25 feet per second, floats were used instead of the meter.

When floats were employed, both surface floats and float rods were used, the latter weighted at the lower end so as just to clear the bed of the river, and with the top standing about ½ inch above the surface. The surface floats were only used on days when there was no appreciable wind.

The length of the measured float run varied from about 30 feet to 300 feet, and the mean of from 3 to 10 runs was taken. Floats which deviated markedly from the centre of the stream were rejected.

SELECTION OF CROSS SECTION.

Whenever practicable, the cross sections were taken following a straight reach of from 100 to 300 feet, free from backwatering, where the river bed was permanent, free from obstructions, and the cross sections fairly even in contour.

In one or two instances where the normal velocity of the river was low, supplementary cross sections, as stated above were taken in very dry weather at narrow points in the river, where the velocity was high enough even in very dry weather to admit of the use of the current meter.

Where the bed of the river was non-permanent, the cross sections were tested after floods, to detect alteration of the section by scour.

METHOD OF TAKING CROSS SECTIONS.

Before the cross section was taken, a peg with a round headed nail driven into the centre was pushed into the margin of the river bed with the top of the nail level with the surface of the water, the object of this being to show any change of river stage during operations.

In the case of the large rivers where a boat was obtainable, a hand line of ¼ inch cord was stretched across the river about 3 feet above the surface, and made secure to trees, or to posts driven in on either bank; 2 feet up stream of this a wire with numbered tags inserted at 5 foot intervals was stretched parallel to the cord.

Soundings were taken from the bows of the boat with a graduated rod at every tag, the boat being brought into position by the hand cord, and moved gradually across the river as required. The level of the river surface was noted before and after the soundings. This plan was used for the Rivers Cam, Chelmer, Colne, Ouse, Derwent, Avon (Stratford) and the South Delph. In the case of the Rivers Tees, Exe, Stour, Maun, Pickering Beck, Stock Beck, Wye, Hart, Ray, Avon (Rugby and Coventry), Showley Brook, Anker, Finham Brook, and Mobberley Brook, boats could not be obtained, and the cross sections were generally obtained by wading. Where the stream was narrow and yet too deep for wading, a weighted graduated line was used, hung from two lengths of ¼ inch gas tubing, a graduated line with a heavy weight attached to the end being thrown across the stream to give the width of stream, and the position of the soundings. With any stream under 30 feet in width, soundings were taken at intervals of from 1 to 2 feet.

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* These pulsations, or impulses, may often be observed by noting the long waving submerged strands of water crow-foot, one minute lying parallel with the axis of the stream, the next minute forming various angles with it.

* With velocities much below ·5 foot per second; as the velocity of the stream decreases so the retarding effect caused by inertia and friction increases. Consequently, the meter registers less than the true velocity. With the particular meter used the greatest percentage error was about 1 per cent. with a velocity of ·43 feet per second.

Points at which the Velocity Records were taken.

In the case of the larger rivers the velocity was generally taken by current meter midway between each pair of soundings (*i.e.*, at 5 feet intervals throughout the cross section in the case of large rivers) unless the cross section was unusually even, when the cross sectional area was sometimes divided up into three or four areas, and the mean velocity of each area was taken.

Depth below the Surface at which Velocity was taken.

As a general rule the velocity was taken at ·6 of the depth of the river at each point, this depth having been found as the result of a very large number of records by various observers to represent the mean velocity in the majority of rivers. In one or two instances, however, during floods, the velocity was taken 1 foot below the surface, and a co-efficient applied to obtain the mean velocity. The period for which the revolutions of the meter were recorded at one point was usually 50 to 100 seconds, and three to six readings were taken at the same point at intervals of about 3 minutes.

In this way two possible sources of error were reduced to a minimum, viz., the effect of pulsations, and retardation of meter by adhering filaments of weed.

In a few instances 600 second counts were taken.

Supplementary vertical velocity curves were generally taken in the centre of the river, but the various mean velocities throughout the whole cross section were not thus ascertained, the time necessary for obtaining the various velocities by this method commonly involving a risk of change of river stage in the meantime.

In the case of the smaller streams and rivers, a temporary dam with thin rectangular brass weir was used whenever possible, the conditions being chosen so as to avoid appreciable velocity of approach, and to secure full contraction on all three sides of the weir, free overfall, and free access of air under the falling sheet of water. The measurements of height of water over weir were taken sufficiently far back to avoid curvature, whilst not far enough back to be affected by surface slopes.

For calculations under these conditions, Smith's co-efficients for weirs in thin walls with complete contraction (·60—·65) were used according to the length of weir and height of water over weir; the formulæ ranging from $Q = 3{\cdot}21 \sqrt{H^3}$ to $Q = 3{\cdot}47 \sqrt{H^3}$.

Q = c.f.s. per foot length of weir.
H = height over weir measured in feet.

Equivalent to $Q = 4{\cdot}63 \sqrt{H^3}$ to $Q = 5 \sqrt{H^3}$ when H is measured in inches, and Q = c.f.m. per foot length of weir.

In the case of Buxton, a large wooden dam was erected across the Wye, and the height of water passing over the weir registered daily for a period of 15 days, by an automatic recorder, the resulting charts being subsequently worked out.

At Rugby the gaugings were carried on continuously over a period of 20 days.

Where permanent wide-crested weirs existed in good condition, and the existing condition of the river precluded other methods of ascertaining the flow, the depth over the permanent weir was taken.

At Coventry the depth flowing over the Bubbenhall Mill weir was recorded on four Sundays (*i.e.*, on days when the mill was not working). Smith's co-efficients—for weirs in thin walls without end contractions—(·62 to ·65) were used in the formula, the corrections (·017 to ·108) to these co-efficients for wide crest of weir being obtained from tables prepared by Fteley and Stearns.*

The formula ranged from $Q = 3{\cdot}4 \sqrt{H^3}$ for a depth over weir of ·1 foot to $Q = 2{\cdot}8 \sqrt{H^3}$ for a depth of ·8 foot. Q being equal to c.f.s. per foot length of weir, H being measured in feet.

In one or two instances the volume of the stream was gauged when flowing through a sluice gate, the head of water on the up-stream side of the gate causing full contraction on all four sides; the area of the fully contracted section was measured, and the current meter held in the centre of the section, the contracted area multiplied by the velocity giving the discharges.

In several cases, notably on the River Avon, mills holding up the water caused difficulties in gauging, the flow of water at the gauging station being at a maximum soon after the mill started, and often tailing off to nearly zero shortly after the mill had ceased working. Consequently, gaugings made under such conditions only gave the *rate of flow* of the river for that particular time, and not the average flow for the 24 hours, which could only be obtained on Sundays.

The flow of such rivers varies from day to day, according to the amount of work being done at the mills. It may then be termed an artificial flow, being much at the mercy of the mill owner in the case of a small river or stream.

The following table shows the method of gauging carried out at each river or stream:—

Alderley Edge and Mobberley Brook.	Cross section and current meter (one gauging). Temporary dam and weir (two gaugings).
Barnoldswick and Stock Beck	Cross sections and floats (one gauging). Cross section and current meter (one gauging).
Berkhamsted. Grand Junction Canal.	Flow supplied by courtesy of Gordon C. Thomas, Esq., M.Inst.C.E., engineer to the Canal Company.
Buxton and River Wye -	Temporary dam and weir (15 gaugings). Cross section and current meter (two gaugings).
Cambridge and River Cam -	Cross section and floats (two gaugings).
Chelmsford and River Chelmer	Cross sections and floats (one gauging). Flow over permanent weir (one gauging).
Consett and River Derwent -	Flow over permanent weir (one gauging). Cross section and current meter (one gauging).
Coventry and River Avon -	Cross section and floats (one gauging). Flow over permanent weir (four gaugings).
Halstead and River Colne -	Cross sections and floats (one gauging). Current meter and cross section (one gauging).
Hartley Wintney and River Hart.	Cross sections and floats (three gaugings).
Huntingdon and River Ouse -	Cross sections and floats (one gauging). Cross section and current meter (two gaugings).
Higham Ferrers and River Nene.	Cross sections and floats (two gaugings).
Kenilworth and Finham Brook	Cross section and current meter (two gaugings).
Lincoln and South Delph -	Cross sections and floats (five gaugings). Temporary dam and weir (one gauging). Cross section and current meter (one gauging).
Malton (Yorkshire) and River Derwent.	Cross section and current meter (three gaugings).
Middleton - in - Teesdale and River Tees.	Cross section and current meter (two gaugings).
Nuneaton and River Anker	Cross section and floats (one gauging).

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* Hydraulics, Bellasis, p. 117, Table XVII.

Ollerton and River Maun -	Cross sections and floats (one gauging). Cross section and current meter (one gauging).
Pickering and Pickering Brook	Cross section and current meter (two gaugings).
Rugby and River Avon -	Cross sections and floats (four gaugings). Flow over permanent weir (20 gaugings).
St. Neots and River Ouse -	Cross sections and floats (two gaugings).
Stratford and River Avon -	Cross section and current meter (one gauging). Cross sections and floats (one gauging). One gauging supplied by courtesy of R. Dixon. Esq., Borough Surveyor.
Swindon and River Ray -	Cross sections and floats (one gauging). Cross section and current meter (one gauging).
Tiverton and River Exe -	Cross section and current meter (one gauging).
Wilpshire and Showley Brook	Cross section and current meter (one gauging). Temporary dam and weir (two gaugings).
Wye and River Stour - -	Cross section and current meter (two gaugings). Cross sections and floats (one gauging).

The results of the gaugings are given below in tabular form. Attention was mainly concentrated upon the sluggish streams during the drought of 1911, since it was with these that nuisance was apprehended.

Name.	Gauging Results. (Flow given in Gallons per 24 hours.)
Alderley Edge and Mobberley Brook - -	* 7,500,000 ; 1,000,000 ; 866,000.
Barnoldswick and Stock Beck - - -	† 2,225,000 ; 1,500,000.
Berkhamsted and Grand Junction Canal -	2,000,000 (not gauged).
Buxton River Wye - - - - -	* 16,000,000 ; 3,500,000 ; § 2,139,600 ; § 2,055,900 ; § 2,057,000 ; § 1,902,960 ; § 1,677,200 ; § 1,748,920 ; § 1,729,670 ; § 1,673,380 § 1,409,920 ; § 1,384,780 ; § 1,362,540 ; § 1,208,280 ; § 1,274,460 ; § 1,257,460 ; § 1,108,680.
Cambridge and River Cam - - -	26,000,000 ; § 20,133,000.
Chelmsford and River Chelmer - - -	13,000,000 ; § 10,584,000.
Consett and River Derwent - - -	† 26,000,000 ; § 8,294,400.
Coventry and River Avon - - - -	‡ 3,976,938 ; † 9,246,000 ; 8,415,000 ; § 5,781,000 ; 7,245,000.
Halstead and River Colne - - - -	† 7,000,000 ; 4,000,000
Hartley Wintney and River Hart -	§ 3,250,000 ; 4,500,000 ; † 6,000,000.
Huntingdon and River Ouse - - -	† 124,000,000 ; * 250,000,000 ; § 95,949,000.
Higham Ferrers and River Nene - -	47,968,000 ; † 55,000,000.
Kenilworth and Finham Brook - - -	2,000,000 ; 1,500,000.
Lincoln and South Delph - - - -	6,930,000 ; * 21,000,000 ; 6,000,000 ; 7,500,000 ; § 2,794,500 ; § 1,500,000 ; § 2,147,250.
Malton and River Derwent - - -	† 234,000,000 ; † 174,000,000 ; 100,810,440.
Middleton and River Tees - - - -	31,500,000 ; † 40,000,000.
Nuneaton and River Anker - - -	‡ 1,700,000
Ollerton and River Maun - - - -	† 13,000,000 ; 8,000,000.
Pickering and Pickering Beck - - -	10,632,000 ; † 17,000,000.
Rugby and River Avon - - - -	‡ 4,000,000 ; ‡ 2,000,000 ; ‡ 1,120,000 ; ‡ 7,481,000 ; † 6,158,080 ; 4,558,796 ; 5,757,460 ; 5,941,100 ; 6,686,855 ; 4,751,306 ; 3,334,570 ; 4,288,425 ; 4,667,045 ; § 2,807,622 ; †7,424,114 ; 3,761,077 ; § 2,790,575 ; 3,418,707 ; 3,864,712 ; 4,199,945 ; § 2,630,002 ; 3,029,832 ; 5,578,585 ; 4,563,685.
St. Neots and River Ouse - - - -	† 162,000,000 ; 95,949,000.
Stratford and River Avon - - - -	† 124,500,000 ; 36,000,000 ; 40,000,000.
Swindon and River Ray - - - -	1,000,000 ; ‡* 32,500,000.
Tiverton and River Exe - - - -	100,000,000.
Wilpshire and Showley Brook - - -	150,000 ; * 2,250,000 ; § 119,000.
Wye and River Stour - - - -	† 56,000,000 ; † 22,680,000 ; § 8,250,000.

NOTE.—All dry weather flows unless otherwise indicated.

* Signifies river in flood.
† Signifies river high.
‡ Signifies rate of flow at time of gauging.
§ Signifies river very low.

It should be observed that to obtain detailed information concerning a particular stream or river entails prolonged and, therefore, expensive observations over a considerable period. Further, a method employed for gauging the flow of one particular river may be quite unsuited to another river or stream of a different character. A usual method of ascertaining the average dry weather flow of a river is as follows :—

The series of gaugings are set down in a table in order of their quantities, and the entire series of observations is divided into four equal parts, the lowest fourth representing extreme droughts and the highest fourth floods. The average of the middle half is ascertained, and all above that quantity of the original table is considered as flood water. A new table is then constructed in which all the gaugings not exceeding the average of the middle half are put down at their actual quantity ; but all that are above the average are put down as equal to that average quantity ; the mean of the whole of the new table is to be considered as a fair average of the water flowing in the stream exclusive of floods.

Such a method, however desirable, would, on the ground of expense alone, owing to the number of observations required, have been out of the question in the present case.

The drought of 1911 occurring towards the end of the stream observations enabled a large number of gaugings to be taken showing the flow of the various rivers and streams during an abnormally dry season, when the flow of many of the rivers was at the lowest known for years.

ADDENDUM TO PART II.

EXTRACTS FROM THE (UNPUBLISHED) INTERIM STREAMS REPORT PRESENTED TO THE COMMISSION BY THE OFFICERS IN MARCH, 1910.

A brief statement with regard to this Interim Report has already been made on p. 62, in the preface to Part II. of this Appendix. A few extracts from it are now given here. It must, however, be again repeated that this Addendum is now superseded by the present Appendix to the Eighth Report.

“ **Rough classification of the streams according to the strength or oxidizability of the sewage liquor or effluent which they receive.**

“ The short reports on the individual streams which constitute Part I. of this report, and of which a brief summary is now given in Table A[1], are sufficient to show the difficulty of drawing general deductions from the data at present available. We may, however, attempt to classify the various streams roughly into four divisions, according to the calculated oxidizability[*] of the liquors which they receive, as follows :—

	Calculated oxidizability (giving credit for nitrate).	Number of streams in this group.
“ Group I. (sewages and tank liquors) - - - -	51 to 154	7
“ Group II. (poor effluents) -	11 to 18	4
“ Group III. (fair effluents) -	5 to 10	10
“ Group IV. (good effluents) -	−8 to 1	4

“ If each of the figures in the first column represented the true oxidizability, and if the streams into which the sewage liquors or effluents were discharged were equally pure, then the figure given by $\frac{\text{oxidizability of effluent}}{\text{degree of dilution}}$ would represent the relative amount of oxidizable impurity in unit volume of the polluted water.

“ It has, however, to be borne in mind that —

“ (1) The figures for oxidizability are only an approximation, though probably they are not very far from the truth.

“ (2) The waters of the streams receiving the various sewage liquors and effluents are of different degrees of purity.

“ (3) The depths and velocities of the streams being different, the suspended solids of the sewages and effluents are distributed over unequal lengths of the bed of the stream.

“ (4) The velocity (and therefore the dilution) has not yet been determined in every case under dry weather conditions.

“ (5) The streams all receive surface water, but what the relative volume of such water is, compared with the volume of the sewage liquor or effluent, and what its degree of impurity, we have no data to show. It might be argued that the polluting power of surface water, generally, cannot be very great, judging from the quality of the water of rivers receiving no sewage liquor or effluent. Against this, however, we have to remember that surface water from uncultivated land, which is sparsely populated, must be different from surface water derived from an area producing sewage or sewage effluent; the surface water in the latter case must undoubtedly be more impure.

“ This difficulty must always be present in connection with the pollution of streams. To obtain even approximate data as regards the various proportions and qualities of surface waters and storm sewages would involve great expenditure of time and money. For this reason we are obliged in this and in any future report to assume that roughly proportional quantities of polluting matter are discharged in the form of storm sewage and surface water at the different places. It is, of course, obvious that this cannot be strictly true.

“ Other points of difficulty might no doubt be brought forward, but the above will probably be considered sufficient. Subject to those provisos, a brief examination may be made of the individual streams and effluents comprising the various groups. The figures of analysis in this and subsequent tables represent parts per 100,000 by weight.

“ Group I.

“ Group I. Place.	Calculated oxidizability of sewage liquor.	Dilution.[**]	$\frac{\text{Oxidizability.}}{\text{Dilution.}}$	Some figures of analysis of sewage liquor.		
				Ammoniacal nitrogen.	Volatile solids.[†]	Dissolved oxygen taken up in 5 days at 18·3° C. (65° F.).
“ Ollerton - - - -	(say) 50	(?) 2,600	0·019			
“ Pickering - -	73	1,750 W.[‡]	0·042 W.	3·91	10·9	26·3
“ St. Neots - -	81	1,600 W.	0·051 W.	6·39	22·0	28·5
“ Huntingdon - -	154	1,000	0·154	6·56	14·6	47·5
“ Wye - - -	(say) 150	660	0·227			
“ Malton - - -	147	300	0·49 W.	5·76	26·0	44·5
“ Barnoldswick - -	51	12·5	4·1	3·58	6·2	14·7

“[*] *Cf.* Appendix IV. to Fifth Report, pp. 1-51.

“[†] The portion of the suspended solids which is volatile on ignition. [‡] “ W ” denotes wet weather dilution.

[1] This Table is not included now, the substance of it having been given in other parts of this Appendix.

[**] The figures for “ dilution ” which are reproduced in this Addendum have been superseded in the present Appendix by others, for which more data were available.

* * * * * * * *

"Group II.

"Group II.	Calculated oxidizability of effluent (giving credit for nitrate).	Dilution.	$\frac{\text{Oxidizability.}}{\text{Dilution.}}$	Some figures of analysis of effluent.			
				Ammoniacal nitrogen.	Nitric nitrogen.	Volatile solids.	Dissolved oxygen taken up in 5 days.
"Middleton -	18	1,400	0·013	2·04	0·27	3·9	3·2
"Tiverton - -	17	200	0·085	1·36	0·15	4·5	4·4
"Rugby - -	11	5	2·20	2·12	0·51	0·9	2·0
"Swindon - -	14	1	14·0	2·10	0·69	2·0	2·5

* * * * * * * *

"Group III.

"Group III.	Calculated oxidizability of effluent (giving credit for nitrate).	Dilution.	$\frac{\text{Oxidizability.}}{\text{Dilution.}}$	Some figures of analysis of effluent.			
				Ammoniacal nitrogen.	Nitric nitrogen.	Volatile solids.	Dissolved oxygen taken up in 5 days.
"Consett - -	5	100	0·05	0·60	0·36	1·2	0·93
"Hartley Wintn'y	9	55	0·16	1·17	0·34	1·6	1·39
"Chelmsford -	9	25	0·36	1·21	0·24	1·3	1·22
"Berkhamsted -	8	20	0·40	0·80	0·35	1·6	1·49
"Wilpshire -	7	15	0·47	0·69	0·23	1·5	1·23
"Cambridge -	8	11	0·73	1·23	0·91	1·6	1·25
"Alderley Edge -	6	10	0·60	0·73	0·48	1·5	1·46
"Lincoln - -	8	5	1·60	1·58	1·53	1·7	1·75
"Nuneaton -	6	3	2·0	1·05	0·74	1·1	1·58
"Coventry -	10	2·5	4·0	2·14	1·11	1·1	0·89

* * * * * * * *

"Group IV.

"Group IV.	Calculated oxidizability of effluent (giving credit for nitrate).	Dilution.	$\frac{\text{Oxidizability.}}{\text{Dilution.}}$	Some figures of analysis of effluent.			
				Ammoniacal nitrogen.	Nitric nitrogen.	Volatile solids.	Dissolved oxygen taken up in 5 days.
"Stratford-on-Av.	– 2	130	– 0·015	0·18	2·62	1·4	0·83
"Halstead* -	2	25	0·080	0·63	1·47	1·2	0·79
"Kenilworth -	– 8	15	– 0·52	0·03	5·27	2·4	0·55
"Buxton - -	1	3·5	0·029	0·13	1·28	1·4	0·78

"* At Halstead, in addition to this good effluent, the river receives untreated night and storm sewage."

* * * * * * * *

After each of the above Groups, I.—IV., comes a description of the state of the stream at each place in the group, followed by a summary and by the conclusions drawn from the observations. The matter of these summaries and conclusions is, however, now practically embodied in Part 1. and Part II., Sections 4 and 5, of the present Appendix, so it is unnecessary to reproduce it here.

Part III. of the Interim Streams Report opened with a section entitled “Correlation of Outside Observations on Streams with Laboratory Tests, with Special Regard to the Question of Standards.” This subject is now discussed more fully in Part II., Section 1, of this Appendix, so it need not be repeated here. The report then goes on to discuss the question of limiting chemical figures, as follows :—

“ LIMITING CHEMICAL FIGURES FOR A RIVER WATER WITHIN WHICH THE WATER WILL SHOW NO SIGNS OF SEWAGE POLLUTION OTHER THAN GREEN WEEDS.

“ Is it possible to say that a river water with a given chemical analysis will or will not show the following signs of sewage pollution :—

“ (1) Deaeration (de-oxygenation) of the water.

“ (2) Growth of fungus.

“ (3) Deposition of mud ?

“ To work out this point in a thoroughly satisfactory way for a given river it would be necessary to keep that river under close observation for a considerable length of time, and to draw a very large number of samples at the spot where all signs of pollution had ceased. This spot would necessarily vary in position to some extent, according to the season of the year and according to the degree of pollution which the river was receiving at the time. The water of even pure streams is bound to deteriorate in quality in times of flood, and this would apply with greater force to streams which normally receive a considerable proportion of polluting matter.

“ Still, although no one river has been kept under such close observation for the Commission, we think that an approximate answer to the above question can be obtained from a general review of the figures of analysis given by the various streams, coupled with the outside observations upon evidences of pollution. With this object in view, we have brought together in Table C. (below) the figures for ammoniacal nitrogen, “ oxygen absorbed ” in 4 hours, dissolved oxygen absorption in 5 days, and suspended solids, given by 42 samples, all drawn at points below which there was (at the times of observation) no sign of sewage pollution other than green weeds.

TABLE C.

	Distance below outfall at which all visible signs of pollution (except green weeds) had ceased. (Feet below outfall).	Analysis.—Parts per 100,000.			
		Ammoniacal nitrogen.	“ Oxygen absorbed ” in 4 hours from $\frac{N}{80}$ permanganate at 27° C. (80° F.).	Dissolved oxygen taken up in 5 days at 18° C. (65° F.).	Suspended solids.
“ Alderley Edge	7,800	0·20	0·43	0·42	2·8
		0·086	1·937	0·62	24·1
“ Barnoldswick	12,800	0·214	0·303	0·41	
		0·657	0·562	0·30	
		0·074	0·256	0·25	
“ Berkhamsted	(say) 5,000	0·185	0·225	0·40	1·0 (ap.)*
		0·172	0·368	0·47	3 to 4 (ap.)
“ Buxton	300	0·063	0·240	0·13	1·5
“ Cambridge	2,500	0·114	0·187	0·26	Trace
		0·214	0·332	0·46	Trace
“ Chelmsford	5,400	0·212	0·297	0·39	2·0 (ap.)
		0·132	0·400	0·33	1·0 (ap.)
		0·067	0·362	0·24	
“ Consett	300	0·028	0·212	0·13	1·5 (ap.)
“ Halstead	5,000	0·152†	0·463		
“ Hartley Wintney	almost at outlet	0·015‡	0·184	0·18	0·5 (ap.)
“ Huntingdon	300	0·030§	0·310	0·25	3·2
		0·011§	0·224	0·10	Trace
“ Kenilworth	4,000	0·054	0·405	0·39	
		0·032	0·442	0·38	
		0·018	0·298	0·23	
“ Lincoln	4,000	0·664	0·445	?	0·5 (ap.)
		0·030	0·561	0·27	8·9
“ Middleton	300	0·006¶	0·121	0·18	
“ Malton	300	0·010‖	0·232	0·20	
“ Nuneaton	1,000	0·224	0·480	0·53	
		0·149	0·389	0·38	
“ Ollerton	900	0·008	0·24	0·26	
“ Pickering	900	0·008	0·439	0·25	
“ Rugby	(say) 1,000	0·151	0·464	0·57	
“ St. Neots	600	0·009**	0·219	0·15	
		0·020**	0·320	0·18	
“ Stratford-on-Avon	300	0·023	0·22	0·05	0·9
		0·012	0·295	0·40	
“ Swindon	4,000	0·152	1·096	0·88	10·7
		0·276	0·911	0·88	3·4
“ Tiverton	300	0·003††	0·068	0·28	0·3 (ap.)
		0·004††	0·103	0·11	
“ Wilpshire	4,000	0·078‡‡	0·017	0·23	
		0·046‡‡	0·441	0·28	
		0·058‡‡	0·21	0·23	
“ Wye (Kent)	3,000	0·033	0·379	0·41	0·5 (ap.)

* “Ap” = approximately, as deduced from the centrifuge figures. † This analysis refers to 3,000 feet below outfall. ‡ This analysis refers to 600 feet below outfall. § These analyses refer to 1,600 and 900 feet below outfall. ‖ This analysis refers to 1,850 feet below outfall. ¶ This analysis refers to 1,000 feet below outfall. ** These analyses refer to 300 feet below outfall, but figures almost the same at 2,400 feet. †† Analyses made at 3,900 and 1,800 feet below outfall. ‡‡ Analyses made at 4,700 and 1,800 feet below outfall.

"Summarising the figures in the foregoing Table C, we find :—

"1. *Ammoniacal Nitrogen.*—Excepting in the case of two samples from Barnoldswick (0·214 and 0·657 Ammon N.), one from Lincoln (0·664), one from Swindon (0·276), one from Nuneaton (0·224), and one from Cambridge (0·214), all the figures for ammoniacal nitrogen in the samples of the waters drawn at points below which there were (at the time) no visible signs of sewage pollution excepting green weeds were below 0·2, and the great majority of them below 0·1.

"2. *'Oxygen absorbed' in 4 Hours at 27° C. from $\frac{N}{80}$ Permanganate.*—Excepting for one sample from Alderley Edge, with 24 parts of suspended solids (1·937 "oxygen absorbed"), one from Barnoldswick (0·56), one from Lincoln (0·56), and two from Swindon with 10·7 and 3·4 parts of suspended solids (1·090 and 0·911), all the figures for "oxygen absorbed" in 4 hours were below 0·5 and most of them below 0·4; the *average* for the thirty-two figures below 0·5 was 0·28.

"3. *Dissolved Oxygen taken up in 5 Days at* 18° *C.*—Excepting for one sample from Alderley Edge (0·62), one from Nuneaton (0·53), one from Rugby (0·57), and two from Swindon (0·88 and 0·89), all the figures for dissolved oxygen absorption in 5 days were below 0·5, and most of them much lower; the *average* for the thirty-two figures below 0·5 was again 0·28.

"The agreement between the figures for 'oxygen absorbed' in 4 hours and dissolved oxygen taken up in 5 days was good in 12 cases, fair in 12, and not good in 8.

"It seems, therefore, a legitimate *tentative* conclusion to say that if the water of a stream is not to show sensible deaeration, to grow fungus, or to give rise to any other signs of sewage pollution excepting green weeds, that water shall not give higher figures of analysis than :—

Ammoniacal nitrogen	0·1
"'Oxygen absorbed' from $\frac{N}{80}$ permanganate in 4 hours, at 27° C.	0·33
"Dissolved oxygen taken up from water in 5 days, at 18° C.	0·33"

The following subsidiary points were then discussed in detail :—

"*Is there anything like a constant ratio between the figures for 'oxygen absorbed' in 4 hours and dissolved oxygen taken up in 5 days?*

* * * * *

"*At what relative rate or rates do the suspended solids of sewage liquors and effluents take up dissolved oxygen from water?*

* * * * *

"*How much oxygen is required for the complete oxidation of the suspended solids of sewage liquors and effluents?*

* * * * *

"*At what relative rate or rates do the liquid portions of sewage liquors and effluents take up oxygen in 1, 2 and 5 days?*

* * * * *

"*Is the actual absorption of oxygen from water by the suspended solids of a sewage liquor or effluent comparable with the absorption by the dissolved impurities?*

* * * * *

"*How far is the actual oxygen content of the water of a stream to be taken as an index of the purity of that water?*

* * * * *

"On p. 184 of this Section of the Report, limiting figures of analysis for a river water are tentatively suggested—for ammoniacal nitrogen, "oxygen absorbed," and dissolved oxygen absorption—if the water is not to show any signs of sewage pollution. It is therefore necessary now to look at the figures of analysis given by the samples of the various waters, drawn *above* the effluent outfalls. Those analysis are to be found in Table D. It will be seen that, so far, there are usually two or three such analyses from each place.

"It may be worth while to look for a moment at the three factors separately :—

"*Ammoniacal Nitrogen.*—The subjoined six samples from (above outfall in) six rivers gave the following high figures :—

"Alderley Edge	0·144
"Cambridge	0·152
"Higham Ferrers	0·181
"Nuneaton	0·140
"Rugby	0·163
"Ollerton	0·175

"The figures for the remaining fifty-five samples from twenty-five rivers were under 0·1, mostly well under it, in the second and third decimal.

* * * * *

"*'Oxygen absorbed' in 4 hours (from $\frac{N}{80}$ permanganate).*—The following nineteen samples from (above outfall in) fifteen rivers gave the figures :—

"Alderley Edge	3·630 1·670
"Berkhamsted	0·388
"Chelmsford	0·421
"Coventry	0·349
"Hartley Wintney	0·698
"Kenilworth	0·698 0·376
"Lincoln	0·475 0·442 0·842
"Middleton	0·360
"Nuneaton	0·376
"Pickering	0·378
"Rugby	0·962
"Swindon	0·934
"St. Neots	0·381
"Wilpshire	0·406
"Wye	0·351

"It will be noted that only eleven of these samples gave a figure which was sensibly above the suggested standard 0·33. The figures of the remaining forty-two samples from twenty-four rivers were under 0·33, and a fair number of them well under it.

"The lowest figures were given by :—

"Buxton	·080
"Consett	·089
"Middleton	·089
"Pickering	·060
"Tiverton	·080

"*Dissolved Oxygen taken up in 5 Days.*—The following nineteen samples from (above outfall in) fifteen rivers gave the figures :—

"Alderley Edge	2·72* 1·02
"Berkhamsted	·80
"Cambridge	·46
"Chelmsford	·41
"Halstead	·47
"Higham Ferrers	·63
"Kenilworth	·84
"Huntingdon	·44
"Lincoln	·59 ·46
"Nuneaton	·46
"Ollerton	·61
"Rugby	·47
"Swindon	·48 ·64
"Stratford	·34
"Wilpshire	·36

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* "The excessively high figures for 'oxygen absorbed' and for dissolved oxygen taken up were due in the case of Alderley Edge to storms bringing down large quantities of suspended solids (69·2 and 16·5 parts in the above two samples of river water).

"The remaining forty-two samples from (above outfall in) twenty-three streams gave figures below the suggested factor 0·33. The following seven streams gave the very low figures :—

"Barnoldswick	·10
"Buxton	·07
"Consett	·05
"Pickering	·06
"Stratford	·07
"Tiverton	·09
"Middleton	·12

"It is thus obvious that, of the three factors tentatively suggested, the one for dissolved oxygen absorption is rather the most stringent, though on the whole they run fairly parallel. For the present, we propose to confine ourselves to this factor.

"We have not sufficient data to enable us to give, with anything like accuracy, figures representing the actual oxidizability of such river waters, but from our general experience we think it would not be very far wrong to put this—especially for the less pure waters—at 3 times the (average) figure obtained for dissolved oxygen absorption in 5 days. If this be accepted for the moment, in order that the point may be discussed on the above lines, then the oxidizability of the river waters, including their suspended solids, would probably work out approximately as follows. The figures given below represent the parts by weight of oxygen required to oxidize completely 100,000 parts of water. For convenience' sake, the same order is adopted as when grouping the various sewage liquors and effluents in Part II. of this Report :—

	Approximate calculated total Oxidizability of River Water.
"*Group I.*	
"Ollerton	1·1
"Pickering	·2
"St Neots	·6
"Huntingdon	·8
'Wye	·6
"Malton	(?) ·7
"Barnoldswick	·5
"*Group II.*	
"Middleton	·4
"Tiverton	·5
"Rugby	1·1
"Swindon	(?) 1·7
"*Group III.*	
"Consett	(?) ·15
"Hartley Wintney	·8
"Chelmsford	·8
"Berkhamsted	1·6
"Wilpshire	·7
"Cambridge	(?) ·9
"Alderley Edge	(?) —
"Lincoln	1·0
"Nuneaton	·6
"Coventry	·8
"*Group IV.*	
"Stratford	·4
"Halstead	·9
"Kenilworth	1·5
"Buxton	·5

* * * * *

Such waters as those at Barnoldswick, Consett, Middleton, Pickering and Tiverton may for all practical purposes be taken as unoxidizable, *i.e.*, as pure, considered as non-drinking waters.*

"Without wishing to strain the point, we think that the data given in this report, after they have been strengthened by further data from dry-weather observations extendin over a hot season, indicate the practicability of calculatin how much effluent of a given quality (*i.e.* a given oxidizability) may safely be allowed to enter a stream of known volume, rate of flow, and quality of water, without giving rise to any appreciable signs of sewage pollution, other than green growths. For sewages and tank liquors the same thing would hold, if it were not for their suspended solids, which must always be more or less of a disturbing factor in sluggish reaches near outfalls, unless the dilution is very great. Two imaginary instances may be given here, in illustration of the above argument :—

"(A) A rather poor river water with a calculated (*total*) oxidizability of 0·8 receives a rather poor effluent of calculated oxidizability 10. What must the dilution be, on the above basis, if all signs of sewage pollution are to be avoided ?

"100,000 parts of :—

"The river water would itself take up in 5 days $\frac{0\cdot8}{3} = 0\cdot27$ parts oxygen. The effluent would itself take up in 5 days $\frac{10}{3} = 3\cdot3$ parts oxygen.

"The river water itself approaches pretty nearly the tentative limiting figure of 0·33, *i.e.*, it will only allow of an addition of 0·06 part, from the incoming effluent. Hence the dilution must be $\frac{3\cdot3}{0\cdot06} = 55$ volumes of water to 1 volume of effluent.

"(B) A pure river water, whose calculated oxidizability is only 0·3, *i.e.* a practically unoxidizable water, receives a sewage liquor of oxidizability 70. The water itself may be assumed to take up little or no oxygen. The sewage liquor will take up about $\frac{70}{3} = 23\cdot3$ parts in 5 days. Hence the dilution must be $\frac{23\cdot3}{0\cdot33} = 71 : 1$.

"In actual practice the dilution in case (B) would probably have to be rather greater than this, unless the stream were a very rapid one, as there would be a tendency for solids from the sewage liquor to deposit near the outfall, giving rise to signs of sewage pollution.

"One or two further instances may be taken, more or less at random, from the places actually under observation.

"(C) The Buxton effluent (including 2·2 parts of suspended solids) took up 0·78 part oxygen in 5 days (8 samples). The river water took up 0·15 part in 5 days (3 samples). The water has thus $(0\cdot33 - 0\cdot15) = 0\cdot18$ part to spare, and hence the dilution may be $\frac{0\cdot78}{0\cdot18} = 4\cdot5 : 1$.

"The actual dilution† is 3 or 4 : 1, and the only sign of sewage pollution—other than abundant green growths—is a little sewage fungus for a short distance below the outfall.

"(D) The very poor Barnoldswick effluent (really a sewage liquor) took up 14·7 parts oxygen in 5 days (8 samples). The river water took up 0·13 part (3 samples). The water has thus $0\cdot33 - 0\cdot13 = 0\cdot20$ part to spare, and hence the dilution might be $\frac{14\cdot7}{0\cdot2} = 74 : 1$.

"The actual dilution is only 10 or 15 : 1, and there are abundant signs of sewage pollution.

"(E) The Lincoln effluent (with 6† parts of solids in suspension) took up 1·75 parts of oxygen in 5 days (8 samples). The Dyke water took up 0·33 part (5 samples). Theoretically, therefore, the dyke water has nothing to spare. Hence the effluent ought on the above basis to be of much higher quality than it is.

"The dry-weather dilution is about 5 : 1, and there are signs of sewage pollution for a long distance below the outfall.

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* "A pure, *i.e.*, unoxidizable, water might give a very small figure for (apparent) dissolved oxygen absorption, from error of experiment, unless the estimation were made with special precautions. It would be well to make a few such estimations on waters of known purity, so as to get this datum."

† These figures for dilution refer only to the years 1908 10.

"(F) The Wilpshire effluent (with 3·3 parts of suspended solids) took up 1·23 parts of oxygen in 5 days (8 samples). The river water took up 0·23 part (3 samples). The water has thus 0·33 – 0·23 = 0·10 part to spare, and hence the dilution should not be less than $\frac{1\cdot23}{0\cdot10} = 12 : 1$.

"The actual dry-weather dilution is about 15 : 1, the current being a sluggish one, and still there are plentiful signs of sewage pollution for half a mile below the outfall. With the sluggish current, therefore, the above dilution, though sufficient in theory, is actually insufficient, no doubt because of the deposition of putrefactive solids below the outfall.

"It is unnecessary to adduce further instances until more data have been accumulated with respect to the river waters above the outfalls. We think, however, that enough has been said to show the reasonableness of applying in this way the dissolved oxygen absorption test for purposes of standards; it is, in fact, the only truly rational method. It would work out somewhat in the following way:—

"We suggest 0·33 as the base figure for dissolved oxygen absorption by a river water in 5 days, because out-of-doors observation taken together with laboratory work has shown that figure to be somewhere near the truth. A subsidiary reason for suggesting this figure, instead of, say, ·35 or ·30, is because it is one-third of the whole number 1.

"An effluent discharged into a stream of pure water, giving a dilution of only 1 : 1, would have a limiting figure for dissolved oxygen absorption in 5 days of 0·33 × 2 = 0·66. So far as our experience goes, there are very few places giving such small dilutions, Birmingham being a notable exception. There the dilution of the effluent is about 1 :1, but the river water itself is far from pure.

"An effluent receiving a dilution of pure water of 2 : 1 would have a limiting figure for dissolved oxygen absorption in 5 days of 0·33 × 3 = 1·0, and so on.

"In cases of very small dilution, the amount of oxygen in solution in the effluent at the time of discharge would obviously be a factor of importance.

"It would probably be impracticable, from an administrative point of view, to have more than, say, the three or four standards suggested by the Commission in their Fifth Report.

"There would be few cases in which the dilution would be less than 2 : 1 and, therefore, in which the standard would need to be higher than 1·0 part of dissolved oxygen absorption in 5 days. This, though rather a high standard, is one which is not at all impracticable to achieve, as shown by the following examples:—

* * * * * * * * * * *

"*Streams Observations.*	Suspended solids.	Dissolved oxygen taken up in 5 days.
"Effluent from Buxton	2·2	0·78 (8)
"Effluent from Consett	2·9	0·93 (7)
"Effluent from Coventry	2·6	0·89 (8)
"Effluent from Halstead	2·3	0·79 (7)
"Effluent from Kenilworth	4·7	0·55 (8)
"Effluent from Stratford-on-Avon	2·6	0·83 (8)

"The smaller the dilution available, the greater care would, of course, have to be taken as regards the non-discharge of suspended solids. However, as has already been shown, the better oxidized an effluent is as a whole, the better oxidized are its solids and the more easily are they settled out.

"When an effluent had to be discharged into a stream, the water of which was not pure, the dilution would, of course, require to be proportionately greater, as outlined on the preceding pages of this Report. But if the above system of standards could be applied in zones to a stream from source to mouth, there being sufficient distance between two polluting discharges to allow of the partial recovery of the water, the water of the stream would not fall below the degree of purity indicated by the factor 0·33 for dissolved oxygen absorption, and the contingency just mentioned would probably not arise.

"*Application of the limiting figure ·33 to the formulation of a fixed legal standard or standards.*

"It might reasonably be argued that from an administrative point of view it would be impracticable to take the quality of a river water into account, when setting a standard for sewage effluents entering that river at various points near to one another, on the following grounds:—

"(1) That in the case of a river receiving effluents from contiguous towns *A* and *B*, the river water would not have time to recover itself, so as to be of the same quality just above the outfall at *B* as it was above the outfall at *A*, and this even though *A* complied with the suggested effluent standard, so as not to bring the quality of the water under a dissolved oxygen absorption of ·33. A higher class effluent would thus be required from *B* than from *A*, *because* of the pollution at A.

"(2) Because it infers a different standard for each place on the stream.

An alternative method of arriving at a fixed *legal* standard, applicable to the majority of cases, would be to assume that the figure ·33 should apply to effluents alone, this constituting the highest or non-dilution standard.

"Since our experience has shown that there are few cases where the dilution of an effluent by a river water is less than 2 : 1, it would follow that the general legal standard for effluents would be 0·33 × 3 = 1·0.

"One or more standards relating to sewages and tank liquors could also be fixed in this way.

"*Whether should an effluent be filtered through paper or merely settled, before the dissolved oxygen absorption test is applied to it, for standard purposes?*

"In the Fifth Report, p. 221, Section 322, a provisional indication is given for the guidance of local authorities of what would generally be considered a satisfactory effluent. Among other things, it is stated in the above section that "an effluent, after being filtered through filter paper, should not absorb more than:—

"(*a*) 0·5 part by weight per 100,000, of dissolved or atmospheric oxygen in 24 hours.

"(*b*) 1·0 part by weight per 100,000, of dissolved or atmospheric oxygen in 48 hours;

"(*c*) 1·5 parts by weight per 100,000, of dissolved or atmospheric oxygen in 5 days."

"This provisional recommendation of filtration through paper has been considerably criticised, on the grounds:—

"(1) That paper filtration may have different effects in the case of different liquids. Thus, a highly oxidized effluent, with well aggregated suspended solids, will filter quite clear and bright, while a poorly oxidized effluent may come through more or less turbid. Further, the quality of the filtrate in the latter case will gradually improve, owing to the straining effect of the fine suspended and gelatinous matter deposited on the paper. This last

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† This high figure was due to one storm sample, which had 19.7 parts suspended solids.

point is well exemplified by the following tests carried out by Mr. Richards, at Dorking, on samples of experimental effluent* there :—

"(1) *February 8th*, 1909.—600 c.c. of a sample of effluent (No. 774) from the coarse shallow percolating filter were passed through (somewhat slow filtering) German filter paper and the filtrate was collected in three fractions of 200 c.c. each.

"The first 200 c.c. required 4 minutes to pass through the paper, and it took up in 5 days, 1·57 parts of dissolved oxygen.

"The second 200 c.c. required 8·5 minutes and took up 0·58 parts of dissolved oxygen.

"The third 200 c.c. required 24·5 minutes and took up 0·70 part of dissolved oxygen.

"The original effluent was brownish, more or less opalescent and rather colloidal, being purposely chosen for that reason. It was poorly oxidized, giving on analysis the figures :—

"Ammoniacal nitrogen - - - - - 4·5
"Nitric nitrogen - - - - - - 0·78
"Dissolved oxygen taken up in 5 days - 5·12

"(2) *March 12th*, 1909.—600 c.c. of a sample of effluent from the coarse shallow percolating filter were treated in the same way :—

"The first 200 c.c. required 2·25 minutes, and took up in 5 days, 1·93 parts of dissolved oxygen.

"The second 200 c.c. required 5·5 minutes, and took up in 5 days 1·05 parts of dissolved oxygen.

"The third 200 c.c. required 18·75 minutes, and took up in 5 days 0·90 part of dissolved oxygen.

"The original effluent, though somewhat turbid, contained very much less suspended solids than No. 774 ; it, too, was poorly oxidized, giving the figures :—

"Ammoniacal nitrogen - - - - - 4·5
"Nitric nitrogen - - - - - - 0·64
"Dissolved oxygen taken up in 5 days - 1·99 (?)

"(2) That the paper and the film produced in the course of the filtration retain a considerable proportion of the bacteria of the effluent.

"It would, of course, be easy to specify a standard method, according to which filtration through paper should be carried out, *e.g.* :—

"(*a*) In a funnel of given size, etc.

"(*b*) With filter paper of given quality, size, and shape.

"(*c*) So much liquid to be passed through the filter in the first instance, and the filtrate from this to be rejected.

"(*d*) After that, a given volume to be filtered.

"Still, even allowing for this, we have now come to the conclusion, after the foregoing work upon effluents entering streams, that the above criticisms are sound, and that, unless the dissolved oxygen absorption test is to be carried out on an effluent, as discharged (*i.e.*, upon the whole effluent, including its suspended solids), it would be advisable to substitute a 2 hours' settlement for paper filtration.

"For practical reasons, settlement in the laboratory must either be for 2 hours or for 24 hours. A 2 hours' settlement allows of the analysis being made on the same day, while with a 24 hours' settlement the analysis has to be put off until the following day, and comparatively little is gained, at least in the case of effluents, in respect of deposition of solids. A 4 or 5 hours' settlement would not merely necessitate a day's delay also, but would generally be inconvenient.

"Two hours' settlement gave the following reduction in suspended solids in the different groups (average figures) :

	Suspended Solids.		Numbers of sample tested.
	Original sample.	Settled for 2 hours.	
Group I. - -	30·1	7·0	(10)
,, II. - -	4·1	1·8	(9)
,, III. - -	2·3	1·4	(18)
,, IV. - -	5·0	1·8	(9)

"The two hours' settlement is easily carried out by shaking up the effluent, contained in a duplicate half Winchester quart, with a bubble of air to act as a mixer ; at the end of 2 hours, a specified volume of the liquid is siphoned off at a given depth.

"The six instances which have been quoted on p. 182 of this Report (Buxton, etc.), show, that if effluent solids are fairly well oxidized, the dissolved oxygen absorption in 5 days by liquid and solid together is under 1·0.

"*Should a Standard Based on Dissolved Oxygen Absorption be made to apply to an Effluent after Two Hours' Laboratory Settlement, or to an Effluent as Discharged into the Stream ?*

"This point is one of such great practical importance that we think it advisable to bring it forward for further consideration.

"In the Fifth Report, page 221, Sections 321 and 322, the liquid portion of an effluent and the suspended solids are separated for purposes of standards ; further, it is stated (Section 322) that an effluent, to be satisfactory, should not contain more than 3 parts per 100,000, of suspended matter.

"The average figure for suspended solids in the 36 effluents of Groups II., III., and IV., as discharged, which are quoted on p.181 of this Report, is 3·4, while the average figure after two hours' settlement in the laboratory is 1·8.

"The average figure for suspended solids of the 46 effluents, quoted on p. 182, from Buxton, Consett, Coventry, Halstead, Kenilworth and Stratford, is 2·9, while the average figure for dissolved oxygen absorption in 5 days by those 46 effluents, *including their suspended solids*, is 0·79.

"It would therefore seem justifiable, and it would certainly be simpler, to apply the dissolved oxygen absorption test for standard purposes to an effluent, as discharged into the stream. No effluent containing much suspended solid could pass the highest standard suggested (viz., 0·66 dissolved oxygen absorption), but a fair to good effluent, with 3 parts of suspended solids or less, would have no difficulty in passing the second highest suggested, viz., 1·0 dissolved oxygen absorption.

"While retaining, therefore, the recommendation that an effluent, to be considered satisfactory, should not contain more than 3 parts of suspended solids, the test for dissolved oxygen absorption might be made on the effluent as discharged.

"In bringing this point forward for re-consideration by the Commission, we are fully alive to the arguments which may be fairly advanced on both sides, and our own views upon it do not entirely harmonise.

"As it is important to accumulate as much data as possible on the subject of this report, we would suggest that a sufficient number of local authorities, who have laboratories connected with their sewage works, should be asked to carry out for the Commission during the next few months determinations—*e.g.*, of ammonia, "Oxygen absorbed," dissolved oxygen absorption and suspended solids on their effluents as discharged, and also on the effluents without their suspended solids. The records thus obtained would help the Commission to judge whether the scheme of standards suggested in this Report was a practicable one or not.

March, 1910.

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* *Cf.* Fifth Report, App. IV., p. 172 *et seq.*

"TABLE D.

"Analysis of River Waters Above Outfall.

"Dates of Drawing and of analysis.		Ammoniacal nitrogen.	Albuminoid nitrogen.	Nitric nitrogen.	Oxygen absorbed in 4 hours from $\frac{N}{80}$ permanganate at 27° C.	Dissolved oxygen taken up in 5 days at 18° C.	Suspended Solids.	Centrifuge.	Ratio of Suspended Solids to Centrifuge Solids.[1]	Chlorine.	Oxygen in Solution.	
"Alderley Edge, 37	1909. Feb. 25 Mar. 1	·043	·026	·180	·298	·15				2·29	1·22	Brownish. Slightly opalescent. Very little fine suspended matter.
"Alderley Edge, 90	June 22 June 23	·144	·282	·196	3·63	2·72	69·2 12·9 vol. 56·3 non vol.	171·7	1 : 2·5	2·23	0·16	Dark and turbid. Excess of fine dark solids. Earthy smell.
"Alderley Edge, 1	Oct. 15 Oct. 18	·074	·088	·125	1·670	1·02	16·5 3·4 13·1	52·3	1 : 3·2	1·77	·51	Brown and slightly opalescent. Much brown suspended solids. No smell.
"Barnoldswick, 68	May 13 May 14	·002	·017	·102	·167	·18		2·1		1·24	1·25	Brownish and slightly opalescent. Some light coloured solids. No smell.
"Barnoldswick, 99	July 2 July 6	·003	·027	·092	·262	·12	·45 ·14 ·31	2·4	1 : 5·3	1·00	·87	Brownish and slightly opalescent. Some light coloured solids. No smell.
"Barnoldswick, 11c	Oct. 28 Nov. 1	·008	·12	·138	·162	·10		6·3		1·08	1·09	Slightly opalescent. A little fine suspended solids. No smell.
"Berkhamsted, 45	Apr. 9 Apr. 20	·005	·034	·210	·217	·40		7·8		1·66	·98	Faintly opalescent. Some very fine suspended solids. No smell.
"Berkhamsted, 101	Aug. 9 Aug. 10	·005	·066	·075	·326	·81	3·2 1·7 1·5	4·5	1 : 1·4	1·43	·89	Greenish tint. Much fine pale solids. Faint sweet smell.
"Berkhamsted, 107	Nov. 11 Nov. 12	·007	·056	·325	·388	·46		20·0		1·72	1·02	Brownish and opalescent. Much pale brown suspended solids. No smell.
"Buxton, 22 - -	Jan. 21 Jan. 25	·007	·009	·160	·080	·12	2·8 0·6 2·2	2·52	1 : 0·9	1·05	1·18	Clear but rather brown, with some suspended solids.
"Buxton, 95 - -	July 23 July 26	·021	·016	·110	·108	·07		5·4		1·23	·80	Slightly opalescent. Fair amount of heavy brownish suspended solids. Faint earthy smell.
"Buxton, 1 - -	Oct. 14 Oct. 15	·006	·010	·128	·245	·15		3·3		0·77	1·04	Bright and clear. Appreciable and fine brown solids. No smell.
"Cambridge, 1 -	Jan. 20 Jan. 22	·019	·012	·44	·142	·18		·6		2·15	1·12	Clear. Trace of very fine solids. No smell.
"Cambridge, 75 -	June 23 June 24	·152	·064	·272	·331	·37 + x		3·6		2·58	·37	Brownish but clear. Trace of suspended solids. No smell.
"Chelmsford, 7 -	Feb. 1 Feb. 3	·025	·016	·36	·201	·19		2·6		3·54	1·21	Very slightly brownish and opalescent. Trace of suspended solids, No smell.

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[1] This is a purely empirical comparison of weight with volume."

" Chelmsford, 1 -	1909. Sept. 23 Sept. 24	·010	·024	·10	·304	·13		2·6		3·40	·86	No notes made.
" Chelmsford,104 -	Nov. 8 Nov. 10	·022	·038	·228 { *Tr* Nitrous *N*	·421	·41		5·0		3·22	1·06	Almost clear and colourless. Appreciable fine light coloured solids. No smell.
" Consett, 90- -	July 1 July 2	·001	·008	·013	·125	·05		·7		1·06	1·03	Bright and clear. Trace of suspended solids. No smell.
" Coventry, 75 -	May 13 May 18	·017	·033	·166	·175	·25	·56 ·25 vol. ·31 non vol.	2·9	1 : 5·2	6·51	·93	Brownish and slightly opalescent. A little fine light coloured suspended solids. No smell.
" Coventry, 109 -	Aug. 21 Aug. 23	·009	·033	·132	·349	·29		5·0		3·72	·64	Slightly brownish and opalescent. Moderate suspended solids. No smell.
" Halstead, 11 -	Feb. 3 Feb. 8	·021	·015	·42	·172	·15		7·9		3·24	1·05	Almost clear. Very little suspended solids. No smell.
" Halstead, 79 -	June 24 June 25	·013	·048	·232	·402	·47		10·6		3·09	·31	Brownish and turbid. Considerable fine light coloured suspended solids. Earthy smell.
" Hartley Wintney, 15	Feb. 10 Feb. 12	·012	·024	·16	·270	·21	2·3 1·2 1·1	11·4	1 : 5·0	1·90	1·17	Very faintly opalescent. Considerable pale brown suspended solids. No smell.
" HartleyWintney, 119	1910. Jan. 12 Jan. 14	·019	·054	·152	·698	·30	4·9 1·4 3·5	3·6	1 : 0.7	1·98	1·06	Very brownish and turbid. Considerable fine brown suspended solids.
" Higham Ferrars. 20	1909. Feb. 17 Feb. 18	·181	·036	·28	·31	·63		6·3		3·40	1·04	Very faintly opalescent. A little pale brown suspended solids. No smell.
" Huntingdon, 34 -	Mar. 10 Mar. 11	·032	·036	·435	·328	·44	2·8 2·0 0·8	7·7	1 : 2·8	2·92	1·14	Brownish and opalescent. Small amount of suspended solids. No smell.
" Huntingdon, 1c -	Sept. 27 Sept. 28	·005	·018	·070	·207	·11		·9		2·78	·84	Bright and clear. Trace of suspended solids. No smell.
" Huntingdon, 113	Dec. 1 Dec. 2	·022	·022	·232	·259	·20		Not done		2·55	1·10	Slightly brownish and opalescent. Trace of fine suspended solids. No smell.
" Kenilworth, 27 -	Feb. 2 Feb. 5	·044	·032	·22	·376	·25		3·1		2·10	1·04	Brownish. A little fine brownish suspended solids. No smell.
" Kenilworth, 96 -	June 28 June 29	·063	·081	·228 { *Tr* Nitrous *N*	·698	·84		8·4		2·51	·42	Brownish and rather opalescent. Moderate amount of fine light solids. Distinct fishy smell.
" Lincoln, 62- -	Apr. 29 Apr. 30	·023	·023	·340	·245	·20		1·8		4·22	1·34	Bright and clear. No visible suspended solids. No smell.
" Lincoln, 1 - -	June 1 June 2	·070	·048	·216	·475	·59		Weed too filamentous.		6·09	1·03	Slightly brownish and opalescent. Much fine green filamentous weed. Earthy smell.
" Lincoln, 1 - -	June 29 June 30	·037	·035	·425	·442	·20		3·0		4·06	·78	Brownish and faintly opalescent. Few suspended solids. No smell.
" Lincoln, (1 + 2) -	July 26 July 27	·020	·034	·050 { ·05 Nitrous *N*	·189	·21		·5		6·01	1·40	Bright No suspended solids. Faint earthy smell.

" TABLE D—*continued*.

" ANALYSIS OF RIVER WATERS ABOVE OUTFALL—*continued*.

" Dates of Drawing and of analysis.		Ammoniacal nitrogen.	Albuminoid nitrogen.	Nitric nitrogen.	Oxygen absorbed in 4 hours from $\frac{N}{80}$° permanganate at 27° C.	Dissolved oxygen taken up in 5 days at 18° C.	Suspended Solids.	Centrifuge.	Ratio of Suspended Solids to Centrifuge Solids.	Chlorine.	Oxygen in Solution.	
	1909.											
" Lincoln, 1 -	Oct. 28 Nov. 1	·022	·077	·200 { ·02 Nitrous N	·842	·46	3·3 { 0·7 vol. 2·6 non vol.	5·0	1 : 1·5		·81	Brownish and very opalescent. A little suspended solids. Faint earthy smell.
" Malton, 55 -	May 3 May 4	·007	·017	·150	·230	·23	1·28 { ·29 ·99	4·4	1 : 3·4	1·96	1·11	Faintly opalescent and brownish. A little pale brown suspended solids. No smell.
" Middleton, 42 -	Mar. 4 Mar. 5	·002	·005	·029	·089	·12	·16 { ·07 ·09			·68	1·32	Bright and clear. No visible suspended solids. No smell.
" Middleton, 87 -	June 4 June 7	·002	·007	·016	·360	·15		·5		·55	1·13	Clear. No suspended solids. No smell.
" Nuneaton, 65 -	May 6 May 10	·032	·038	·325	·321	·17	·70 { ·30 ·40	5·9	1 : 8·4	8·19	1·02	Clear and brownish. Fair amount of fine brown suspended solids.
	1910											
" Nuneaton, 170 -	Jan. 13 Jan. 17	·140	·046	·312	·376	·46		8·4		3·25	·95	Rather brownish and opalescent Considerable fine suspended solids. Slight earthy smell.
" Ollerton, 50 -	Apr. 22 Apr. 23	·009	·027	·525	·242	·13	·85 { ·22 ·63	5·2	1 : 6·1	3·39	1·07	Clear. Moderate amount of moss-like solids. No smell.
" Ollerton, 110 -	Nov. 16 Nov. 19	·175	·034	·55 { ·06 Nitrous N	·314	·61		2·6		3·80	1·01	Clear. Brownish. A good deal of suspended solids. No smell.
" Pickering, 60 -	May 4 May 6	·003	·007	·128	·134	·06	·45 { ·18 ·27	1·4	1 : 3·1	1·71	1·08	Bright and clear. A little light coloured suspended solids. No smell.
" Pickering, 84 -	June 29 July 1	·004	·015	·060	·378	·08		7·7		1·49	·90	Brownish and faintly opalescent. Few solids. No smell.
" Rugby, 70 -	May 12 May 13	·163	·041	·192	·313	·47	·50	4·2	1 : 8·4	3·00	·96	Slightly brownish and opalescent. A little fine light coloured suspended solids. No smell.
" Rugby, 105 -	Aug. 20 Aug. 24	·021	·030	·148	·456	·22		5·0		2·32	·66	Slightly brownish and opalescent. A very little fine brown suspended solids. No smell.
" St. Neots, 57 -	Mar. 25 Mar. 27	·016	·028	·440	·280	·31		8·4		2·50	1·08	Slightly brownish and very opalescent. Considerable fine light coloured solids. No smell.
" St. Neots, 6c -	Sept. 28 Sept. 30	·009	·024	·128	·288	·10		1·6		2·81	·78	Very slightly brownish and opalescent. Trace of suspended solids. No smell.

" St. Neots, 116 -	1910 Dec. 14 Dec. 16	·010	·027	·188	·381	·22		*Tr*		1·94	1·18	Brownish and rather opalescent. Little fine suspended solids. No smell.
" Stratford, 19 -	1908 Sept. 5 Sept. 9	*·024	·024	·430 { ·02 Nitrous *N*	·240	·07	·56 { ·32 vol. ·24 non vol.	—	—	5·14	·77	Clear and bright.
" Stratford, 80 -	1909 May 27 May 28	·009	·040	·174 { ·04 Nitrous *N*	·256	·34	·8 { ·35 ·45	5·4	1 : 6·8	3·27	·83	Clear, brownish. Few solids. No smell.
" Stratford, 125 -	Aug. 26 Aug. 29	·007	·020	·168	·176	·07		7·2		1·65	·71	Milky in appearance. Considerable fine light coloured solids. No smell.
" Swindon, 29 - -	Mar. 8 Mar. 10	·038	·074	·312	·962	·48	8·1 { 2·5 5·6	7·7	1 : 1·0	2·20	1·02	Brownish and turbid. Considerable fine suspended solids. No smell.
" Swindon, 164 -	1910 Jan. 11 Jan. 12	·074	·074	·144	·934	·64	5·1 { 0·9 4·2	10·4	1 : 2·0	2·26	1·01	Very brownish and opalescent. Considerable fine suspended solids. Slight earthy smell.
" Tiverton, 25 - -	Feb. 24 Feb. 25	·003	·008	·096	·080	·26	·18 { ·09 ·09	·9	1 : 5·0	1·30	1·29	Clear. Trace of suspended solids. No smell.
" Tiverton, 128 -	Nov. 2 Nov. 4	·003	·010	·108	·107	·09		2·6		1·26	1·09	Bright and clear. Trace of suspended solids. No smell.
" Wilpshire, 32 -	Feb. 9 Feb. 22	·044	·032	·14	·158	·36	·26 { ·13 ·13	·9	1 : 3·5	2·05	1·36	Bright and clear. Trace of suspended solids. No smell.
" Wilpshire, 93 -	June 23 June 25	·017	·027	·100	·406	·16		5·4		1·55	0·86	Faintly opalescent. Small amount of brown solids. No smell.
" Wilpshire, 20*c* -	Oct. 29 Nov. 2	·016	·016	·152	·190	·18		2·6			1·17	Faintly opalescent. A little fine suspended solids. No smell.
" Wye, 39 - -	Apr. 1 Apr. 2	·027	·026	·262	·351	·22		4·0		2·90	0·98	Brownish and opalescent. A little brown suspended solids. No smell.
" Wye, 84 - -	June 1 June 3	·004	·033	·100	·283	·19		2·6		2·85	·67	Brownish but clear. Little suspended solids. No smell.

"* Nitrogens in this case done on paper-filtered sample.

"[1] This is a purely empirical comparison of weight with volume."

PART III.

CHANNEL EXPERIMENTS.

Early in the history of the Commission, Mr. Willis, then Secretary, urged the importance of attempting to correlate the figures of chemical analysis yielded by sewages and effluents with actual results produced when such liquors are discharged. As a step towards gaining definite knowledge on this point, he suggested that useful information might be obtained by running liquors of known and different composition along dry channels, so that the various factors involved might be brought under control.

These channel experiments are the result.

As will be seen from what follows, the conditions in artificial channels are not entirely on all fours with those which obtain in natural streams. Thus, the flow of the liquor in the channel is not subject to natural variations such as occur in a river, nor does the channel receive flushes of storm water from towns, roads, or cultivated land. Among important distinctions thus brought about in a channel, as opposed to a river, are :—

(1) The accumulations of mud in the channel are not scoured out periodically, thus making the condition of the channel worse than the river.

(2) On the other hand, the shallowness of liquid in the channel greatly facilitates re-oxygenation.

These two factors must, to a certain extent, counterbalance one another, but, on the whole, we are disposed to think, as the result of our experience, that the dilution afforded by a river would not give such good security against causation of objectionable conditions as the same dilution in the case of a channel.

In all, ten channel experiments on sewage liquors and effluents have been made, at Chorley, Kingston and Caterham. They consisted simply in allowing sewage effluents, mixtures of effluent with untreated tank liquor, tank liquor diluted with water, etc., to flow along V-shaped wooden channels made of 9-inch boarding, and varying from 50 to 120 yards in length. Natural conditions of streams as to rate of flow and bed of channel were reproduced as well as possible by small dams, and by placing pebbles, small stones and earth in the bottom of the wooden troughs.

The depth of liquid in the channels varied from about ½ inch to 4 inches. The current velocity was sluggish on the average, but it varied from rapid behind each dam to very sluggish in front.

The volume of liquor passing down the channels each day ranged from 1,000 gallons, in some of the Chorley experiments, to about 5,000 gallons at Caterham, and 6,000 gallons at Kingston.

The duration of the experiments, with effluents and mixtures of effluent and tank liquor, was from 4 to 6 months. The experiments at Chorley on the dilution of tank liquor with water lasted 17 months.

SERIES I.

Experiments with Filter Effluents alone.

Three types of filter effluent were chosen :—

(1) An effluent (from a strong sewage) which gave figures for albuminoid nitrogen and oxygen absorbed from permanganate high enough to obtain its condemnation if judged by the ordinary standards of purity now in use, but which, on account of its comparatively slow rate of taking up dissolved oxygen from water would pass the provisional standard suggested by the Commission in their Fifth Report. The experiment with this effluent was made at Caterham.

(2) Effluents fairly well purified as regards carbonaceous matter, but containing most of their combined nitrogen in the unoxidized form. An effluent of this kind, if obtained from a weak sewage would not infringe the usual standards, but would take up oxygen from water fairly quickly. The experiments with effluents of this kind were carried out at Kingston.

(3) A well oxidized effluent such as would, at the present time, generally be considered good. The experiment with this class of liquid was made at Chorley.

Experiment (1).

Caterham Filter Effluent.

The effluent used in the artificial channel at Caterham was derived from a very strong ammoniacal sewage, by passing the latter upwards through a septic tank filled with large flints, then through a graded coke percolating filter, and finally through a second tank filled with flints to arrest suspended matter. The channel was 80 yards long and the flow of effluent through it continuous.

The experiments lasted from February to November, 1907.

During this time the effluent from the final flint tank was a bright liquid with a brownish colour. It had a slight tendency to froth on shaking. It was invariably non-putrescible on incubation for 5 days at 80° F.

Early in March a dark green algal growth made its appearance throughout the whole length of the channel. This developed rapidly and in the course of the next fortnight the deeper parts of the channel became quite full of it.

During a warm and dry period of weather in July great numbers of birds resorted to the channel to feed on larvæ and to drink and bathe, there being no natural stream near. The result was that the channel became practically cleared of growth, the detached filaments being carried to the end of it, where the accumulated mass decomposed and turned black. On August 1st a wire covering was placed over the channel, and by August 13th the channel had practically resumed its former appearance being again full of dark green growth. Early in October, during cold wet weather, the growth began to break up, and by October 21st the channel was almost clear again, the growth being mainly accumulated in the last section of trough and undergoing decomposition.

No grey growth showed in any part of the channel until December, when, owing to the clogging of the septic (cultivation) tank, the effluent from the final " flint " tank deteriorated so greatly in quality as to become very bad. When this happened the whole of the channel became coated with grey fungus.

Throughout the whole period of observation the average analysis of the effluent as entering and leaving the channel was as follows :

CATERHAM FILTER EFFLUENT.

Average of 21 Samples—Parts per 100,000.

	No. of Samples.	Effluent entering channel.	No. of Samples.	Effluent leaving channel.
Ammoniacal nitrogen - - -	7	**5·10** (3·50—6·63)	7	**4·71** (3·10—5·92)
Albuminoid nitrogen - - -	7	**0·32** (0·16—0·49)	7	**0·31** (0·16—0·49)
Nitrous nitrogen - - - -	21	**0·26** (0·03—0·50)	21	**0·32** (0·03—0·63)
Nitric nitrogen - - - -	7	**7·90** (5·80—9·42)	7	**7·80** (5·04—9·36)
Total nitrogen - - - -	5	**13·56** (11·70—15·68)	4	**12·55** (9·70—14·64)
Oxygen absorbed from $\frac{N}{8}$ permanganate—at once - - -	21	**0·91** (0·58—1·26)	21	**0·95** (0·58—1·41)
Oxygen absorbed from $\frac{N}{8}$ permanganate—in 4 hours at 80° F. -	21	**3·01** (1·97—4·30)	21	**3·09** (1·94—4·19)
Incubator test (by smell) - -	21	All passed	21	All passed
Oxygen in solution - - -	20	**0·18** (0·00—0·45)	19	**0·54** (0·08—0·83)
Dissolved oxygen taken up in 48 hours at 65° F. - - -	14	**0·88** (0·37—2·67)	14	**0·71** (0·19—2·67)
Dissolved oxygen taken up in 5 days at 65° F. - - - -	18	**1·28** (0·42—3·70)	19	**1·25** (0·21—4·40)
Solids in suspension (approximate)*	—	**1·1** (0·25—2·2)	—	**0·8** (0·00—2·3)
Solids by centrifuge (volumes) -	19	**10·80** (2·4—21·8)	19	**7·86** (0·00—23·1)
Chlorine - - - - - -	20	**11·34** (8·41—14·12)	19	**11·48** (8·39—14·18)

* These "approximate" figures for solids in suspension are only to be taken as giving a rough idea of the amounts actually present. They are deduced from the centrifuge figures through the aid of the figures for suspended solids and centrifuge figures to be found in Appendix III. to the Fifth Report under Caterham and Chorley.

The figures of analysis given in the above table include the suspended matter in the effluent.

The average figures also include the bad samples of effluent produced at the end of the experiment.

From a careful review of the whole of the figures the following may be looked upon as broadly representing the effluent which produced only green growth.

	Parts per 100,000.	
	Effluent with suspended solids.	Standards which the effluent would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	3·0	4·0
Incubator test (by smell) -	+	+
Dissolved oxygen taken up in 48 hours at 65° F. -	0·75	1·5
Dissolved oxygen taken up in 5 days at 65° F. -	1·0	2·0

This effluent produced not only green growth in the channel, but encouraged it in very great quantity owing to the large amount of nitrogenous and other nutrient matter which the effluent contained.

At the end of the experiment when the effluent had deteriorated in quality and had given rise to a considerable amount of grey growth, its chemical characteristics were shown by the following figures :—

	Effluent with its suspended matter.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - - - - -	4·0
Incubator test (by smell) - - - -	+
Dissolved oxygen taken up in 48 hours at 65° F. - - - - - - -	2·25
Dissolved oxygen taken up in 5 days at 65° F. - - - - - -	4·0

On the whole there was a distinct tendency for the effluent to improve as it flowed down the channel, and that the vegetable growth played a part in this is seen when some of the figures of analysis relating to particular periods are compared.

PERIOD A.

From March to June when the green growth was fully developed.

	Parts per 100,000.	
	Effluent entering channel.	Effluent leaving channel.
Ammoniacal nitrogen - -	4·94	4·53
Dissolved oxygen taken up in 5 days at 65° F. - - -	1·08	0·91

PERIOD B.

From the latter part of June to the end of July when the channel had been cleared of growth by birds.

Dissolved oxygen taken up in 5 days at 65° F. - - -	1·25	1·23

PERIOD C.

From August 13th to October, when the growth was in full development again.

Dissolved oxygen taken up in 5 days at 65° F. - - -	1·06	0·85

The conclusions to be drawn from the channel experiment at Caterham are :—

(1) That an effluent of this kind favours the luxuriant development of green growth.

(2) That while the growth is in process of development no nuisance whatever arises, but that when it becomes detached, either naturally in the autumn or by other causes, it accumulates, turns black, and putrefies, giving rise to obnoxious smell and deoxygenating the water.

(3) That the development of green growth tends to the purification of the water in which it is growing.

EXPERIMENT (2).

Kingston Single Contact Bed Effluents.

Two effluents were separately used for the channel experiments at Kingston. They were both derived from the treatment of the sewage—which was of about average strength—by the A.B.C. precipitation process, followed by single contact beds composed of medium to fine material.

The contact beds were small experimental ones, each $\frac{1}{200}$th of an acre in area and 3 feet deep, filled with coke and clinker respectively. The whole effluent from each bed was discharged in the usual way into its own channel. Each bed was emptied and filled six times per day, this high rate of filtration (about 300 gallons per cube yard per day) being chosen in order to obtain the type of effluent desired for the experiment.

The artificial channels, which were each 50 yards in length, were laid with only a small gradient so as to allow some effluent to stand in them after the beds had run off. When the beds were being emptied, there was a depth of about 4 or 5 inches of effluent water in these channels, but when they were filling or resting, it was only from 1 to 2 inches.

The experiments lasted from July, 1907, to October, 1908, during which time 19 sets of samples were fully examined. Throughout practically the whole of this period the condition of the channels showed little variation, the sides, stones, etc., being covered with patches of both grey and dark green growth. The grey growth flourished mainly at the inlet end of the channels, and the green at the outlet end. In the channel receiving the effluent from the coke bed there was a greater quantity of green growth than in the channel receiving the effluent from the clinker bed, and this growth grew nearer to the inlet end in the former case. Samples of the growths submitted to the Royal Botanic Gardens, Kew, were described as consisting mainly of a variety of the *Vorticellinæ* (grey) and *Stigeoclonium protensum* (green).

In the spring of 1908 a smell of sulphuretted hydrogen could be noticed over the inlet end of each channel during periods of stagnation, and the stagnant effluents turned milky through the precipitation of sulphur. The smell from the channel receiving the effluent from the clinker bed was distinctly worse than the smell from the other channel.

With the advent of warmer weather the smell disappeared.

Neither the green nor the grey growth developed to any great extent in the Kingston channels, nor was any tendency to become detached apparent.

The small development of growths and the relatively slight improvement effected on the quality of the effluents as they flowed down the channel was no doubt due to the circumstance that, when a contact bed was emptied, nearly all its effluent passed through and out of the channel at once.

Only a very small quantity of the effluent remained for any length of time in contact with the growths. Since all samples of effluent, both as entering and leaving the channel, were taken in the middle of the period occupied in emptying the beds, they did not include the above small fraction.

The tendency of effluents of this kind to cause nuisance from smell and to promote grey growths is clearly shown by the experiments.

The following figures of analysis, averages of 19 samples in each case, refer to the precipitation liquor which was being treated and the two effluents entering and leaving the channels.

KINGSTON EXPERIMENTAL FILTER EFFLUENTS.

Parts by weight per 100,000.	No. of Samples.	Precipitation liquor.	No. of Samples.	Clinker bed effluent entering Channel.	No. of Samples.	Clinker bed effluent leaving Channel.	No. of Samples.	Coke bed effluent entering Channel.	No. of Samples.	Coke bed effluent leaving Channel.
Ammoniacal nitrogen - - -	(16)	**2·88** (1·27—4·33)	(18)	**2·71** (1·35—3·80)	(17)	**2·69** (1·55—3·98)	(18)	**2·54** (1·08—3·99)	(18)	**2·49** (1·12—3·72)
Albuminoid nitrogen - - -	(16)	**0·32** (0·14—0·55)	(18)	**0·17** (0·11—0·25)	(18)	**0·17** (0·11—0·27)	(18)	**0·15** (0·07—0·35)	(18)	**0·14** (0·06—0·32)
Nitrous nitrogen - - - -	(13)	**0·03** (0·00—0·10)	(19)	**0·00** (0·00—0·04)	(19)	**0·00** (0·00—0·04)	(18)	**0·00** (0·00—0·04)	(19)	**0·00** (0·00—0·08)
Nitric nitrogen - - - -	(13)	**0·41** (0·00—1·02)	(18)	**0·09** (0·00—0·70)	(18)	**0·10** (0·00—0·68)	(18)	**0·18** (0·00—0·94)	(18)	**0·17** (0·00—0·79)
Total nitrogen (Kjeldahl) - - -	(17)	**4·26** (2·80—6·95)	(13)	**3·19** (1·95—4·58)	(12)	**3·14** (2·28—4·32)	(13)	**3·08** (2·15—4·20)	(13)	**3·02** (2·18—4·18)
Oxygen absorbed from $\frac{N}{8}$ permanganate *at once* - - - -	(19)	**0·89** (0·54—1·29)	(19)	**0·34** (0·13—0·54)	(19)	**0·32** (0·15—0·51)	(19)	**0·30** (0·15—0·54)	(19)	**0·29** (0·14—0·46)
Oxygen absorbed from $\frac{N}{8}$ permanganate *in 4 hours at* 80° F. - -	(19)	**4·18** (2·24—8·00)	(19)	**1·17** (0·45—1·81)	(19)	**1·20** (0·40—1·88)	(19)	**1·07** (0·57—1·93)	(19)	**1·09** (0·54—2·06)
Incubator test (scudder) - - -	—	—	(19)	9 passed 10 failed	(19)	13 passed 6 failed	(18)	13 passed 5 failed	(19)	15 passed 4 failed
Incubator test (by smell) - - -	—	—	(19)	8 passed 2 doubtful 9 failed	(19)	11 passed 2 doubtful 6 failed	(19)	11 passed 3 doubtful 5 failed	(19)	13 passed 2 doubtful 4 failed
Oxygen in solution - - - -	—	—	(18)	**0·17** (0·00—0·36)	(18)	**0·25** (0·00—0·52)	(18)	**0·17** (0·00—0·36)	(18)	**0·29** (0·00—0·55)
Dissolved oxygen taken up in 48 hours at 65° F. - - - -		—	(17)	**0·61** (0·00—1·66)	(18)	**0·56** (0·12—1·63)	(18)	**0·49** (0·00—1·46)	(18)	**0·46** (0·00—1·41)
Dissolved oxygen taken up in 5 days at 65° F. - - - - - -	— —	—	(17)	**1·34** (0·65—2·84)	(17)	**1·33** (0·50—2·60)	(16)	**1·11** (0·70—4·2 + x)*	(16)	**1·13** (0·60—4·1 + x)*
Solids by centrifuge (volumes) - -	(19)	**13·13** (2·8—33·0)	(19)	**9·0** (trace—21·8)	(19)	**11·6** (trace—36·6)	(18)	**7·9** (trace—28·8)	(17)	**8·6** (trace—27·2)
Chlorine - - - - - - -	(19)	**6·81** (4·99—8·14)	(19)	**6·88** (5·09—7·97)	(19)	**6·90** (5·15—7·94)	(19)	**6·91** (5·18—8·01)	(19)	**6·95** (5·21—7·95)
Solids in suspension - - - -	(17)	**2·40** (1·7—4·20)	—							
Volatile matter in solids in suspension	(17)	**1·70** (1·1—3·3)	—							

* + x means that the whole of the dissolved oxygen in the diluting water was used up.

The above figures include the suspended matter of the effluents.

It will be seen that both effluents sent down the channel were very variable in quality, but the following figures may probably be taken as being broadly representative:

	Clinker bed effluent with suspended matter.	Coke bed effluent with suspended matter.	Standards which both effluents would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	1·00	1·00	1·15
Incubator test (by smell)	⅓ putrescible.	¼ putrescible.	—
Dissolved oxygen taken up in 48 hours at 65° F. -	0·75	0·60	1·0
Dissolved oxygen taken up in 48 hours at 65° F. -	1·35	1·10	2·0

It will be seen, therefore, that although the two effluents produced objectionable results in the channels, yet they both passed the usual standards for oxygen absorbed from permanganate.

The effluent from the coke bed was throughout rather better than the effluent from the clinker bed, the *calculated* oxidizability of the two effluents as entering the channel (giving credit for nitrate), being on the average 13·5 and 14·7 respectively.

Little improvement appeared to take place in either effluent as the result of flowing down the channel, but indeed this would not be looked for seeing that the bulk of the effluents passed down in rapid flushes.

EXPERIMENT (3).

Chorley Filter Effluent.

The Chorley filter effluent was used for this experiment. It was derived from a sewage of about average strength by chemical precipitation and quiescent settlement followed by rapid percolating filtration through shallow filters of coarse to very fine material (gravel and coarse sand).

The experiment was started in January, 1907, and continued until September, 1908, during which period 31 sets of samples were examined. The channel was 50 yards long, and the flow through it was continuous.

At the entrance end of the first section of the channel there were always a few tufts and strands of grey growth, these being more evident in winter than in summer.

At no time did this growth, identified at Kew, as *Cladothrix Dichotoma,* extend for more than 3 yards down the channel.

In the warmer months of the year a light green filamentous growth (*Microspora abbreviata, Lagerh*), developed throughout the length of the channel and flourished in the deeper parts to a considerable extent, but this broke up at the first frost and, except for sediment, left the channel practically clean.

The average figures of analysis for the effluent entering and leaving the channel throughout the whole period are as follows:—

CHORLEY FILTER EFFLUENT.

	No. of Samples.	Filter effluent as entering channel.	No. of Samples.	Filter effluent as leaving channel.
Ammoniacal nitrogen - - -	9	**1·11** (0·24—2·21)	9	**1·19** (0·15—2·15)
Albuminoid nitrogen - - - -	9	**0·10** (0·06—0·18)	9	**0·10** (0·07—0·20)
Nitrous nitrogen - - - -	31	**0·005** (0·00—0·07)	31	**0·04** (0·00—0·20)
Nitric nitrogen - - - - -	9	**1·94** (1·23—2·88)	9	**2·45** (1·35—4·00)
Total nitrogen (Kjeldahl) - - -	4	**3·29** (2·27—4·51)	4	**3·70** (2·29—6·62)
Oxygen absorbed from $\frac{N}{8}$ permanganate *at once* at 80° F. - - -	31	**0·17** (0·00—0·39)	31	**0·19** (0·04—0·55)
Oxygen absorbed from $\frac{N}{8}$ permanganate *in 4 hours* at 80° F. - -	31	**0·68** (0·34—1·43)	31	**0·76** (0·11—1·68)
Incubator test (smell) - - -	31	All passed	31	All passed
Oxygen in solution when analysed -	31	**0·62** (0·09—0·97)	31	**0·88** (0·33—1·16)
Dissolved oxygen taken up *in 48 hours* at 65° F. - - - - -	25	**0·18** (0·00—0·40)	25	**0·19** (0·01—0·97)
Dissolved oxygen taken up *in 5 days* at 65° F. - - - - -	29	**0·60** (0·07—2·42)	29	**0·57** (0·22—2·27)
Solids in suspension (approximate)* -	—	**0·6** (trace—2·0)	—	**0·35** (0·00—2·2)
Solids by centrifuge (volumes) - -	29	**7·26** (trace—23·8)	29	**4·40** (0·00—27·0)
Chlorine - - - - - -	30	**7·29** (3·02—10·9)	30	**7·99** (3·50—12·01)

* *See* note to Caterham experiment.

The above figures of analysis include the suspended matter of the effluent.

Excepting for one sample, drawn at the beginning of the experiment, which gave the figure 2·91 for dissolved oxygen taken up in five days, the effluent was of fairly even quality.

The following figures may be taken as broadly representative:

	Parts per 100,000.	
	Effluent with suspended matter.	Standards which the effluent would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	0·30	1·25
Incubator test (by smell) -	+	+
Dissolved oxygen taken up in 48 hours at 65° F. -	0·17	0·25
Dissolved oxygen taken up in 5 days at 65° F. -	0·50	0·80

Beyond traces of grey growth at the inlet end this effluent produced no objectionable results in the channel. Such a liquid might be considered as fit to discharge into any watercourse without dilution.

SERIES II.

EXPERIMENTS WITH UNPURIFIED TANK LIQUOR AND MIXTURES OF SUCH LIQUOR WITH FILTER EFFLUENT.

These experiments were all made at Chorley. The liquors used were four in number, viz.:—

(1) A mixture of filter effluent (3 parts) and well clarified precipitation liquor (1 part).

(2) A mixture of filter effluent (1 part) and well clarified precipitation liquor (1 part).

(3) Well clarified precipitation liquor alone.

(4) The Chorley general discharge. This consisted mainly of filter effluent, but it also contained, as a rule, a small percentage of unfiltered tank liquor and occasionally a large percentage; during storm times it contained, in addition, a preponderating quantity of unpurified storm sewage.

In each case the channel was 50 yards long and the flow of liquor through it continuous.

Experiment (1).

A Mixture of Filter Effluent (3 *parts*) *and Tank Liquor* (1 *part*).

This experiment began in January, 1907, and ended in July, 1907, 12 sets of samples being examined.

By the end of February there was a thin coating of grey growth throughout the length of the channel. This continued, though without further development, until the middle of April, when a light green filamentous growth began to show in the last 10 or 15 yards of the channel gradually extending as time went on towards the inlet end. In June the grey growth in the first 30 yards of the channel became very brown with suspended matter and apparently ceased to develop. By the end of July the channel contained nothing but green algae and brown debris (dead growth and suspended matter), the latter being now entirely converted into small tubiform cases, similar to the larger larvæ cases made by caddis worms. To these cases countless bubbles of gas adhered.

There was no great development of growth either grey or green at any time and no nuisance from smell was observed, but the bottom of this channel became rather fouled with a brown deposit.

In the early part of the year when the grey growth predominated the channel had an unclean appearance.

The average figures of analysis for the mixture as entering and leaving the channel are as follows :—

Chorley Effluent and Tank Liquor.

	No. of Samples.	Mixture of effluent (3 parts) and tank liquor (1 part) as entering channel.	No. of Samples.	Mixture of effluent (3 parts) and tank liquor (1 part) as leaving channel.
Ammoniacal nitrogen - - - -	7	**1·60** (0·81—2·86)	7	**1·35** (0·22—2·15)
Albuminoid nitrogen - - - -	7	**0·16** (0·12—0·25)	7	**0·14** (0·07—0·20)
Nitrous nitrogen - - - -	12	**0·06** (0·00—0·42)	12	**0·05** (0·00—0·25)
Nitric nitrogen - - - - -	7	**1·44** (0·67—2·29)	6	**1·71** (0·88—2·82)
Total nitrogen (Kjeldahl) - - -	2	**3·84** (3·72—3·95)	3	**3·44** (3·16—3·92)
Oxygen absorbed from $\frac{N}{8}$ permanganate—at once at 80° F. - -	12	**0·40** (0·08—0·68)	12	**0·29** (0·08—0·53)
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	12	**1·47** (0·81—2·30)	12	**1·14** (0·57—1·91)
Incubator test (by smell) - - -	12	All passed	12	All passed
Oxygen in solution when analysed -	12	**0·38** (0·04—0·81)	12	**0·52** (0·17—1·06)
Dissolved oxygen taken up in 48 hours at 65° F. - - - - - -	7	**0·92** (0·48—1·70)	7	**0·30** (0·05—0·72)
Dissolved oxygen taken up in 5 days at 65° F. - - - - - -	10	**1·45** (0·55—2·72)	11	**0·84** (0·12—1·40)
Solids by centrifuge (volumes) - -	9	**14·0** (2·5—30·2)	10	**5·48** (0·0—14·4)
Chlorine - - - - - - -	12	**7·62** (5·96—9·82)	12	**7·23** (5·41—9·69)

The above figures of analysis include the suspended matter in the mixture.

The mixture was of variable quality, but the following figures may be taken as broadly representative :—

	Mixture with suspended matter.	Standards which the effluent would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	1·5	2·25
Incubator test (by smell) -	+	+
Dissolved oxygen taken up from water in 48 hours at 65° F. - - - -	0·80	1·5
Dissolved oxygen taken up from water in 5 days at 65° F. - - - -	1·25	2·50

The conditions of channel actually observed indicate that the mixture giving these figures would not be sufficiently pure to discharge into a dry ditch.

It will be noticed that all samples of the mixture, both as it entered and left the channel, were non-putrescible.

Considering the short length of the channel, the improvement in the mixture as shown by the figures of the table is very marked. This is especially the case with regard to the decrease in the figures for dissolved oxygen taken up in 48 hours and 5 days and the increase in that for nitric nitrogen.

Experiment (2).

A Mixture of Filter Effluent (1 *part*) *and Tank Liquor* (1 *part*).

This experiment began in August, 1907, and ended in September, 1908, 19 sets of samples being examined.

Grey growth began to show in the channel immediately after starting. In October, 1907, this extended about half way down the channel. Moreover, underneath the growth there was now a deposit of black putrid mud, and in consequence of the sulphuretted hydrogen given off from this the grey growth was itself coated with a yellowish white deposit of sulphur.

In the first 10 yards or so the growth was vigorous, but beyond this it did not appear to be flourishing, and its development was apparently impeded by the decomposition of the black mud.

In the lower half of the channel there was at this time a considerable quantity of green growth. This was practically all covered with brown suspended matter and could only be detected on careful examination. Most of the detached growth and brown suspended matter was in the form of larvæ cases. There was some grey growth in this part of the channel too, and some thin white strands of a growth not previously noticed in any of these channel experiments.

Early in November great numbers of gnat larvæ appeared in the channel. By November 14th these had almost all hatched out and disappeared.

Throughout the winter the channel remained in much the same condition, excepting that the grey growth tended to predominate more, only small patches of green growth being visible latterly.

With the return of warm weather in April, 1908, the conditions began to alter and by the end of May the green growth was flourishing by itself along the greater part of the channel, the grey growth being now confined to the first 10 yards or so. The appearance of the channel underwent no change from this time until September when the experiment ended. Throughout the summer the green growth was covered with a brown deposit and for this reason the channel compared very unfavourably in appearance with the channel receiving effluent alone.

During the whole period throughout which the experiment lasted, 19 samples of the mixture were taken both as it entered and left the channel. The following are the average figures of analysis :—

CHORLEY EFFLUENT AND TANK LIQUOR.

	No. of Samples.	Mixture of effluent (1 part) and tank liquor (1 part) as entering channel.	No. of Samples.	Mixture of effluent (1 part) and tank liquor (1 part) as leaving channel.
Ammoniacal nitrogen - - -	2	**2·40** (1·78—3·03)	2	**2·29** (1·79—2·79)
Albuminoid nitrogen - - -	2	**0·14** (0·12—0·15)	2	**0·12** (0·11—0·12)
Nitrous nitrogen - - - -	19	**0·12** (0·00—1·00)	19	**0·08** (0·00—0·40)
Nitric nitrogen - - - - -	2	**0·67** (0·53—0·80)	2	**0·99** (0·37—1·60)
Total nitrogen (Kjeldahl) - - -	2	**3·58** (2·79—4·36)	2	**3·68** (2·50—4·85)
Oxygen absorbed from $\frac{N}{8}$ permanganate at once at 80° F. - -	19	**0·45** (0·09—1·20)	19	**0·33** (0·04—0·93)
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	19	**1·60** (0·70—2·80)	19	**0·98** (0·41—1·80)
Incubator test (by smell) - - -	19	14 passed 4 doubtful 1 failed	19	All passed.
Oxygen in solution when analysed -	19	**0·46** (0·00—0·91)	19	**0·57** (0·10—0·94)
Dissolved oxygen taken up in 48 hours at 65° F. - - - - -	18	**1·13** (0·18—2·35)	18	**0·36** (0·00—0·84)
Dissolved oxygen taken up in 5 days at 65° F. - - - - -	18	**2·10** (0·51—3·75)	18	**0·96** (0·23—2·30)
Solids by centrifuge (volumes) - -	19	**16·5** (8·4—23·6)	19	**4·0** (0·00—18·0)
Chlorine - - - - - -	19	**7·19** (3·04—11·08)	19	**7·27** (2·96—11·45)

The figures include the suspended matter in the mixture.

The mixture was rather variable in quality, but the following figures may probably be taken as representative :—

	Parts per 100,000.	
	Mixture (1 part effluent and 1 part tank liquor) with its suspended solids.	Standards which the mixture would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	1·5	2·50
Incubator test (by smell) -	+	+
Dissolved oxygen taken up in 48 hours at 65° F. -	1·25	1·75
Dissolved oxygen taken up in 5 days at 65° F. -	2·25	3·00

It is clear that this liquor would produce obnoxious results if discharged into a dry ditch.

As in the case of the other mixture of tank liquor with effluent the change which took place as the liquid passed down the channel was marked, the improvement showing itself in every figure of analysis but especially in those for dissolved oxygen absorption in 48 hours and 5 days.

The following conclusions seem to be indicated by these two experiments with mixtures of well clarified precipitation liquor with good filter effluent :—

(*a*) That even a small proportion of unoxidized precipitation liquor with effluent favours the development of grey growth in a channel along which the mixture is allowed to flow.

(*b*) That the quantity of grey growth (or in other words the length of channel along which it develops) depends upon the proportion of unoxidized precipitation liquor present.

(*c*) That mixtures of precipitation liquor and well oxidized effluent undergo rapid change in warm weather when allowed to flow along a channel—through absorption of oxgyen.

(*d*) That the unoxidized suspended matter in the precipitation liquor deposits in the sluggish reaches of the channel there undergoing putrefaction.

EXPERIMENT (3).

Well Clarified Precipitation Liquor Alone.

The precipitation liquor used in this experiment resulted from the treatment of the Chorley sewage by the addition of 8 grains per gallon of alumino-ferric followed by quiescent settlement in tanks for about 2 hours. It may be described as a slightly opalescent liquid with a faint greenish brown tinge, and containing on the average less than two parts of suspended matter per 100,000.

The experiment began in August, 1907, and lasted until September, 1908, during which period 19 sets of samples were examined.

Grey growth began to develop all down the channel immediately the experiment started. This was only a very transitory condition, however, for when the deposits of putrefying suspended matter in the sluggish parts of the channel became appreciable, the growth appeared to be killed.

From October, 1907, until the end of the experiment in September, 1908, grey growths could be seen in the first trough and in those parts of the channel where the flow was rapid, but in the sluggish reaches it was practically absent throughout.

During the same period, *i.e.*, for practically the whole time of the experiment, the black putrefying sludge lying in the slack water was more or less covered with a dark green growth (*Ulothrix Subtilis*). In the winter months this appeared to diminish in quantity and it had not a very bright colour, but from May until September, 1908, it formed a brilliant dark green covering to practically the whole of the deposited black sludge.

A few strands of green filamentous growth and also of grey growth were present in the last section of the channel, but the condition of the liquid was evidently unfavourable to both, and they never showed marked development.

It was noticeable that in the first few yards of the trough where the grey growth persisted throughout no *Ulothrix Subtilis* appeared at any time.

During the experiment some 19 samples of the precipitation liquor were drawn at each end of the channel. They gave the following average figures of analysis :—

CHORLEY TANK LIQUOR.

Parts per 100,000.

	No. of Samples.	Precipitation liquor as entering the channel.	No. of Samples.	Precipitation liquor as leaving the channel.
Ammoniacal nitrogen - - -	2	**3·10** (1·90—4·30)	2	**3·20** (2·06—4·33)
Albuminoid nitrogen - - -	2	**0·27** (0·18—0·35)	2	**0·30** (0·26—0·33)
Nitrous nitrogen - - - -	16	**0·02** (0·00—0·16)	16	**0·02** (0·00—0·20)
Nitric nitrogen - - - -	—	—	—	—
Total nitrogen (Kjeldahl) - -	2	**3·74** (2·55—4·93)	2	**3·71** (2·51—4·91)
Oxygen absorbed from $\frac{N}{8}$ permanganate *at once* at 80° F. - -	19	**0·71** (0·20—1·57)	19	**0·66** (0·14—1·61)
Oxygen absorbed from $\frac{N}{8}$ permanganate *in 4 hours* at 80° F. - -	19	**2·65** (1·03—5·09)	19	**2·38** (0·87—4·54)
Incubation test (by smell) - -	19	2 passed 17 failed	19	5 passed 14 failed
Oxygen in solution - - - - -	19	**0·27** (0·00—0·82)	19	**0·33** (0·00—0·84)
Dissolved oxygen taken up *in 48 hours* at 65° F. - - - -	15	**2·39** (0·25—4·45)	15	**1·93** (0·20—4·56)
Dissolved oxygen taken up *in 5 days* at 65° F. - - - - -	16	**4·91** (1·20—9·28)	16	**4·00** (0·78—7·18)
Solids in suspension (approximate)*	—	**3·0** (0·8—4·3)	—	**2·1** (0·2—6·4)
Solids by centrifuge (volumes) - -	19	**22·7** (6·3—33·0)	19	**16·5** (1·8—48·8)
Chlorine - - - - - -	18	**7·23** (3·08—12·71)	18	**7·00** (2·97—11·67)

* *See* note to Caterham experiment.

The figures include the suspended matter contained in the tank liquor.

The liquor varied very much in quality according to the strength of the sewage dealt with, but the following figures may probably be taken as giving a general idea of the usual composition.

	Tank liquor with its suspended solids.	Standards which the tank liquor would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	2·75	4·5
Incubator test (by smell) -	Putrid	All putrescible
Dissolved oxygen taken up in 48 hours at 65° F. -	2·50	4·0
Dissolved oxygen taken up in 5 days at 65° F. -	5·0	8·0

The liquor would undoubtedly produce offensive results if discharged into a dry ditch.

There was a slight but by no means marked general improvement in the liquor as the result of its passage down the channel, but it must be remembered with regard to this that the greater part of the passage was over putrefying mud. On several occasions the liquor leaving the channel had a distinct smell of sulphuretted hydrogen.

The main points brought out by this experiment seem to be :—

(*a*) That the evils which occur in a sluggish stream as the result of the discharge of unoxidized precipitation liquor into it are mainly nuisance from smell and the fouling of the bed of the stream, the fouling being caused by the cumulative deposition of putrescent solids and also to some extent by algal growths.

(*b*) That the unoxidized precipitation liquor in an undiluted state does not favour the development of the grey or green growths which are promoted by partially oxidized or well oxidized tank liquors. If the channel or ditch receiving such a liquor were sufficiently long, however, growths would no doubt appear in large quantity lower down.

EXPERIMENT (4).

The Chorley General Discharge.

This consisted mainly of filter effluent but it also contained as a rule a small proportion of unfiltered tank liquor, and occasionally a large proportion ; during storm times it contained in addition a preponderating quantity of storm sewage.

The experiment lasted 180 days, from January to July, 1907. During this time the channel received a constant quantity of filter effluent and tank liquor mixed in varying proportions, while the storm overflow worked 166 hours in 74 flushes.

The volumes of liquid discharged into the channel during the whole period were :—

Effluent and tank liquor (constant), about 60,000 gallons.

Storm water (in flushes), about 40,000 gallons.

In other words, out of the total volume of liquid sent down the channel, 40 per cent. was storm water and 60 per cent. effluent with tank liquor.

From the day upon which the first discharge of storm water occurred, the channel was practically full of putrefying sludge. A small quantity of grey growth was usually present in the first few yards of the channel, and during spells of dry weather grey or green growth (according to whether it was winter or summer) developed in all those parts of the channel where the flow was rapid enough to prevent the accumulation of mud.

In July, a dark green growth (*Ulothrix Subtilis*) developed and spread considerably over the surface of the deposited sludge, but speaking generally the channel may be said to have presented a black and very unpleasant appearance, its bottom in the sluggish reaches being badly fouled with putrefying mud. Any disturbance of this mud caused a smell over the channel, and the liquid in the absence of storm water always appeared to deteriorate in its passage along the channel. As it flowed in, it was generally clear and odourless, or nearly so, while as it left the channel it was milky and often possessed a strong unpleasant smell.

The following average figures, which refer only to the mixed tank liquor and effluent (no samples of storm sewage being included), show that the mixture did deteriorate as the result of passing over the sludge.

CHORLEY.

Parts per 100,000.

	No. of Samples.	Mixed effluent and precipitation liquor as entering the channel.	No. of Samples.	Mixed effluent and precipitation liquor as leaving the channel.
Ammoniacal nitrogen - - - -	6	1·60	6	1·68
Albuminoid nitrogen - - - -	6	0·19	6	0·14
Nitrous nitrogen - - - - -	11	0·04	11	0·04
Nitric nitrogen - - - - -	6	1·09	6	0·57
Oxygen absorbed from $\frac{N}{8}$ permanganate at once at 80° F. - - -	11	0·36	11	0·46
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	11	1·31	11	1·30
Incubator test (by smell) - - -	11	10 passed 1 failed	11	8 passed 2 doubtful 1 failed
Oxygen in solution when analysed -	10	0·38	11	0·57
Dissolved oxygen taken up in 48 hours at 65° F. - - - - -	6	0·35	6	0·60
Dissolved oxygen taken up in 5 days at 65° F. - - - - -	10	0·78	10	1·07
Solids by centrifuge (volumes) - -	8	8·9	9	6·5
Chlorine - - - - - -	11	7·35	11	7·71

These figures have, of course, little relation to the results produced in the channel. In spite of long periods of dry weather the solid matter deposited from the storm sewage was the preponderating influence in this experiment.

SERIES III.

EXPERIMENTS WITH DILUTED TANK LIQUOR.

The two channel experiments with diluted tank liquor were made at Chorley.

They began on June 18th, 1909, and, except for stoppages for frost during the winter, continued until November 19th, 1910, a period of 17 months.

In each experiment a mixture of very well clarified and somewhat weak Chorley precipitation liquor and Chorley towns water was allowed to flow slowly along a channel, 120 yards in length, fitted with small wooden dams.

The mean current velocity in the channels was a very low one of about 6 feet per minute.

In one experiment (Channel No. 1) the mixture was composed of tank liquor (1 part) and water (19 parts) by volume. In the other (Channel No. 2), the mixture was composed of tank liquor (1 part) and water (9 parts), by volume.

The following average figures will give an idea of the composition of the liquids before mixture:

	Chorley precipitation liquor. Average of 4 sets of hourly Samples (drawn in July and August 1903.)	Chorley town water. Average of 4 chance Samples (drawn in June, July and November, 1910.)
Ammoniacal nitrogen -	3·64	0·005
Albuminoid nitrogen -	0·57	0·016
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	4·86	about 0·15*
Chlorine - - - -	9·22	1·027
Solids in suspension -	2·89	Trace
Dissolved oxygen taken up in 48 hours at 65° F. -	—	0·05
Dissolved oxygen taken up in 5 days at 65° F. -	—	0·15

* This figure is calculated from an average figure of 0·097 for oxygen absorbed in 4 hours from $\frac{N}{80}$ permanganate.

The mixtures sent into the channels should thus have given some such figures as the following on analysis:—

	Mixture of tank liquor (1 part) and water (19 parts.)	Mixture of tank liquor (1 part) and water (9 parts).
Ammoniacal nitrogen -	0·18	0·37
Oxygen absorbed from $\frac{N}{80}$ permanganate in 4 hours at 80° F. - -	0·38	0·62
Chlorine - - - -	1·43	1·84

In what follows it will be seen that the mixture of tank liquor (1 part) and water (19 parts), as flowing into No. 1 Channel, was, if anything, rather stronger than it should have been, while that of the tank liquor (1 part) and water (9 parts), as flowing into No. 2 Channel, was rather weaker than it should have been.

The difficulty in maintaining a steady flow of a small volume of a liquor such as sewage precipitation liquor is well known. It need not specially be taken into account here, however, except in so far as it affects the question of improvement or deterioration of the mixtures as they passed down the channels.

The experiments began on June 18th, 1909.

Grey and green algæ made their appearance in both channels within a few days. Only small quantities were present in either channel, but the development of both kinds of growth was greater in Channel No. 2, than in Channel No. 1.

By the end of August, the green algal growth was abundant in both channels, but it now had a brownish appearance due to deposited suspended matter.

The grey growth showed up mainly at the inlet ends of the channels, but small tufts of it could be seen about halfway along No. 1 and more than half-way along No. 2.

In October and November the growths appeared to reach their maximum development for the year. There was, at this time, an abundance of green growth in both channels, though the quantity in No. 2 was visibly greater than that in No. 1.

The grey alga, identified at Kew as *Cladothrix Dichotoma*, was now confined to the first 5 yards in No. 2 Channel and to the mixing box in No. 1 Channel.

A sample of the green alga sent to Kew was identified as *Microspora Abbreviata, Lagerh.*

Frost was experienced at Chorley during the last week of November, 1909, and the channels, being exposed, were frozen over. When the frost gave way the bulk of the algal growth was seen to be lying detached in the pools in front of the dams. Either there was not a sufficient quantity of the growth, or else the conditions were unfavourable to rapid decomposition, for no offensive conditions can be said to have arisen (*Cf.* Caterham experiment).

Occasional frosts occurred up to the middle of February, 1910. At this time the green growth had practically disappeared from both channels. The grey growth was also affected by the frost, but it did not entirely disappear from either channel.

In March, 1910, the green *Microspora Abbreviata* made its appearance again and developed rapidly. In May it was abundant in both channels, No. 2 being practically filled with it from end to end. There appeared to be about half as much of it in No. 1 as in No. 2.

A month later the green growth in the first half of each channel began to appear brown owing to a deposit of suspended matter, while much debris had now been converted into the tubiform larvæ cases, as in Series II., Experiment (1). Bubbles of gas also appeared on the larvæ cases, especially in Channel No. 2.

During this month (June, 1910), cattle were let into the field in which the channels were placed, and by drinking from the latter greatly disturbed the growths.

At the same time the weather was warm and fairly dry, and the tank liquor stronger than it had been since the winter.

From one cause or the other, probably from both together, the two channels deteriorated in appearance.

On July 21st a fair quantity of grey growth could be seen at the inlet end of each channel, and in No. 2 Channel it was traceable for about 30 yards.

For about 50 yards from the inlet end, moreover, the bottom of Channel No. 2 was almost covered with a deposit of black putrid mud. Channel No. 1 carrying the weaker mixture also looked rather dirty, but it contained no black mud.

In considering the condition of the channels at this time, it should be noted that No. 2 Channel was easily accessible to the cattle, and No. 1 only accessible with difficulty. No. 2 may be considered as being the only channel materially affected by the cattle.

In August, 1910, the channels were fenced in, and from this time to the end of the experiment on November 19th, 1910, they continued to have much the same general appearance, except that the black mud in Channel No. 2 became coated with a thin layer of dark green algal growth which gave the channel the appearance so characteristic of a stream heavily charged with poor sewage effluent.

Speaking generally, therefore, Channel No. 1 may be looked upon as having kept clean throughout the experiment, though appearing rather dirty in the warmer months, while Channel No. 2 kept clean until the summer of 1910, and then became visibly fouled. The disturbance of green weed by cattle undoubtedly had something to do with the fouling of Channel No. 2, but not everything. The spread of the grey growth down the channel is clear evidence that the mixture had become stronger at this time.

The following tables give the average figures of analysis of the mixtures as entering and leaving the channels :—

CHANNEL NO. 1.—CHORLEY TANK LIQUOR (1 PART), WATER (19 PARTS.)

Parts per 100,000.

	Mixture entering Channel.				Mixture leaving Channel.			
	No. of Samples.	Average of 6 chance Samples.	No. of Samples.	Average of 7 hourly Samples.	No. of Samples.	Average of 6 chance Samples.	No. of Samples.	Average of 7 hourly Samples.
Ammoniacal nitrogen	6	**0·31** (0·08—1·03)	7	**0·19** (0·04—0·40)	6	**0·14** (0·07—0·26)	7	**0·19** (0·05—0·38)
Albuminoid nitrogen	6	**0·05** (0·02—0·13)	7	**0·03** (0·02—0·08)	6	**0·04** (0·02—0·06)	7	**0·03** (0·02—0·03)
Nitrous nitrogen	6	**0·00** (0·00—trace)	7	**0·00** (0·00—0·02)	6	**0·00** (0·00—0·00)	7	**0·00** (0·00—0·02)
Nitric nitrogen	6	**0·07** (0·02—0·12)	7	**0·03** (0·00—0·05)	6	**0·06** (0·00—0·12)	7	**0·04** (0·00—0·11)
Total nitrogen (Kjeldahl)	5	**0·25** (0·04—1·16)	—	—	4	**0·30** (0·13—0·52)	—	—
Oxygen absorbed from $\frac{N}{8}$ permanganate at once at 80° F.	5	**0·13** (0·00—0·27)	—	—	5	**0·11** (0·03—0·25)	—	—
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	6	**0·49** (0·14—1·17)	7	**0·28** (0·07—0·55)	6	**0·41** (0·08—0·65)	6	**0·25** (0·07—0·44)
Incubator test (by smell)	5	All passed	—	—	5	All passed	—	—
Dissolved oxygen taken up in 48 hours at 65° F.	6	**0·26** (0·11—0·64)	7	**0·24** (0·08—0·55)	6	**0·09** (0·00—0·17)	7	**0·16** (0·01—0·31)
Dissolved oxygen taken up in 5 days at 65° F.	6	**0·47** (0·28—0·80)	7	**0·32** (0·06—0·64)	6	**0·26** (0·14—0·37)	6	**0·23** (0·03—0·45)
Chlorine	6	**1·35** (1·10—2·98)	7	**1·57** (1·20—2·17)	6	**1·27** (1·17—1·64)	7	**1·52** (1·16—2·03)
Solids by centrifuge (volumes)	5	**3·36** (0· 2—10·8)	7	**1·07** (0·20—2·20)	5	**1·94** (Trace—9·0)	7	**2·60** (0·70—3·80)
Dissolved oxygen in solution when analysed	5	**0·59** (0·09—0·88)	—	—	5	**0·89** (0·52—1·12)	—	—

The above figures are inclusive of the very small quantity of suspended matter which the liquors contained.

The following figures may be taken as representative of the liquor entering the channel:—

	Parts per 100,000.	
	Mixture of tank liquor water (19 parts) as (1 part) and entering channel.	Standards which the mixture would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	0·35	0·75
Incubator test (by smell)	+	+
Dissolved oxygen taken up in 48 hours at 65° F.	0·25	0·50
Dissolved oxygen taken up in 5 days at 65° F.	0·45	0·75

The mixture giving the above figures on analysis gave rise practically to no offensive conditions in the channel.

CHANNEL NO. 2.—CHORLEY TANK LIQUOR (1 PART) AND WATER (9 PARTS).

Parts per 100,000.

	Mixture entering Channel.				Mixture leaving Channel.			
	No. of Samples.	Average of 6 chance Samples.	No. of Samples.	Average of 7 hourly Samples.	No. of Samples.	Average of 6* chance Samples.	No. of Samples.	Average of 7 hourly Samples.
Ammoniacal nitrogen	6	**0·32** (0·10—0·85)	7	**0·39** (0·06—0·87)	5	**0·16** (0·09—0·26)	7	**0·37** (0·08—0·83)
Albuminoid nitrogen	6	**0·06** (0·02—0·09)	7	**0·04** (0·01—0·09)	5	**0·04** (0·02—0·06)	7	**0·04** (0·02—0·08)
Nitrous nitrogen	5	**0·00** (0·00—trace)	7	**0·00** (0·00—trace)	5	**0·00** (0·00—trace)	7	**0·00** (0·00—trace)
Nitric nitrogen	6	**0·05** (0·00—0·11)	7	**0·03** (0·01—0·05)	5	**0·06** (0·00—0·10)	7	**0·03** (0·01—0·06)
Total nitrogen	5	**0·46** (0·11—1·02)	—	—	4	**0·21** (0·10—0·39)	—	—
Oxygen absorbed from $\frac{N}{8}$ permanganate at once at 80° F.	5	**0·14** (0·03—0·32)	1	**0·11**	4	**0·06** (0·04—0·17)	—	—
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F.	6	**0·40** (0·14—0·75)	7	**0·48** (0·10—0·90)	5	**0·33** (0·14—0·55)	7	**0·46** (0·21—0·64)
Incubator test (by smell)	5	All passed	—	—	4	All passed	—	—
Dissolved oxygen taken up in 48 hours at 65° F.	6	**0·23** (0·02—0·62)	7	**0·38** (0·11—1·16)	5	**0·22** (0·08—0·45)	6	**0·22** (0·03—0·55)
Dissolved oxygen taken up in 5 days at 65° F.	6	**0·54** (0·00—1·70)	7	**0·56** (0·16—1·16)	5	**0·38** (0·17—0·96)	7	**0·36** (0·15—0·92)
Chlorine	6	**1·72** (1·19—2·80)	7	**2·10** (1·24—3·45)	5	**1·40** (1·11—1·62)	7	**2·06** (1·26—3·36)
Solids by centrifuge (volume)	5	**2·36** (trace—6·5)	7	**2·40** (0·20—3·8)	4	**1·30** (0·30—5·00)	7	**5·90** (1·80—13·40)
Dissolved oxygen in solution when analysed	5	**0·59** (0·07—0·88)	—	—	4	**0·82** (0·70—1·00)	—	—

* One sample which was putrescible and which gave altogether abnormal results has been omitted from the average.

The above figures are inclusive of the suspended matter which the mixtures contained. The amount of suspended matter was so small, however, as to be almost negligible in the analysis.

The following figures may be taken as representative of the liquor entering the channel :—

	Parts per 100,000.	
	Mixture of tank liquor (1 part) and water (9 parts) as entering channel.	Standards which the mixture would generally pass.
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	0·45	0·75
Incubator test (by smell) -	+	+
Dissolved oxygen taken up in 48 hours at 65° F. -	0·35	0·50
Dissolved oxygen taken up in 5 days at 65° F. -	0·55	0·75

The mixture yielding the above figures of analysis gave rise to no objectionable conditions in the channel as a general rule. In the summer of 1910, however, the channel became visibly fouled for reasons which have just been stated.

The two sets of hourly samples drawn in dry weather on July 8th to 10th, 1910, *i.e.*, just previous to the deterioration in the appearance of the channels, gave the following average results :—

	Mixture of tank liquor (1 part) and water (19 parts) as entering Channel No. 1.	Mixture of tank liquor (1 part) and water (9 parts) as entering Channel No. 2.
Ammoniacal nitrogen -	0·35	0·65
Albuminoid nitrogen -	0·06	0·07
Oxygen absorbed from $\frac{N}{8}$ permanganate in 4 hours at 80° F. - -	0·45	0·75
Dissolved oxygen taken up in 48 hours at 65° F. -	0·35	0·60
Dissolved oxygen taken up in 5 days at 65° F. -	0·50	0·70

SUMMARY.

The meaning of the results obtained in these several channel experiments is best seen when the broadly representative figures given in the foregoing pages are plotted out graphically against the observed condition of the channel.

Whether the condition of a channel is called good or fair, poor or bad, however, depends to some extent upon the person making the observations, and this should especially be borne in mind in what follows.

The channels, in our opinion, should be ranged in the following order, according as they were good or bad from observation. (*Cf.* Table on p. 201.)

Liquor flowing down the channel.	Condition of channel.	Summarized description of condition of channel.
1. Chorley filter effluent alone	Good.	January to September. *Winter.*—A few tufts of grey growth throughout period, but never extending more than three yards down the channel. *Summer.*—Light green filamentous growth throughout, but mostly in deeper parts of channel. This broke up with first frost, but except for sediment left channel clean.
2. Chorley tank liquor (1 part) and water (19 parts)	Fair.	*First Summer and Autumn.*—Quickly developing green and grey growths. The former became very abundant, but as time went on was brownish from deposit of suspended matter. Grey mainly at inlet, but present half-way down channel. *Winter.*—Green growth killed by frost became detached but did not decompose. Grey growth did not entirely disappear. *Second Summer and Autumn.*—Conditions of first summer repeated. Larvæ cases abundant, beaded with bubbles. No mud. For conditions of channel in July *see* below.
3. Caterham filter effluent alone	Doubtful.	*Winter.*—In 6 weeks from February dark green growth throughout channel; deeper parts full of it. *Summer and Autumn.*—July—Birds detached growth which accumulated and decomposed. Channel wired therefore. Subsequently green growth again filled channel, breaking up however in October, accumulating at lower end and decomposing. *N.B.*—No grey growth at all till effluent became bad in December.
4. Chorley tank liquor (1 part) and water (19 parts), July, 1910.	Doubtful.	By the middle of July, 1910, a fair quantity of grey growth at inlet of channel. Latter dirty looking, but contained no mud. *N.B.*—Tank liquor in July stronger than in winter, and the channel perhaps interfered with by cows.
5. Chorley tank liquor (1 part) and water (9 parts)	Doubtful.	*First Summer and Autumn.*—Quickly developing green and grey growths. The former became very abundant, and later brownish from deposit of suspended matter. Grey growth mainly at inlet end. *Winter.*—Green growth killed by frost became detached but did not decompose. Grey growth did not entirely disappear. *Second Summer and Autumn.*—Conditions of first summer repeated. Green growth filled channel and became brown. Mud produced in channel in July (?) by cattle. Later overgrown by green weed.
6. Chorley tank liquor (1 part) and filter effluent (3 parts).	Poor.	*Winter and Spring.*—Grey growth throughout in thin coatings. *April.*—Light green filamentous growth in lower channel and extending to inlet. *June.*—Grey growth limited to upper 30 yards and ceased to develop. *July.*—Green growth alone in channel, but tending to be covered with brown debris and bubble-covered larvæ cases. *N.B.*—No great development of either growth. No smell nuisance. Channel, however, fouled by brown deposit, and especially unclean in appearance when grey growth predominated.
7. Chorley tank liquor (1 part) and water (9 parts), July, 1910.	Bad.	By middle of July grey growth 30 yards down channel, which was deteriorated for 50 yards by deposit of putrid black mud. This mud, produced (?) by interference from cattle, later (after fencing of channel) overgrown by green weed.
8. Kingston coke filter effluent	Bad.	*Summer and Autumn.*—Patches of grey and dark green growth on sides of, and on stones in channel; the former most abundant at inlet—the latter at lower end. *Spring.*—Smell of sulphuretted hydrogen over inlet—effluent milky where stagnant. *Warm Weather.*—Smell disappeared. *N.B.*—Neither growth developed to any great extent, nor had growths tendency to become detached. No serious nuisance can be said to have arisen. Condition of No. 8 generally more satisfactory than that of No. 9 (clinker), channel.
9. Kingston clinker filter effluent	Bad.	Generally as in case No. 8, but less satisfactory on the whole.
10. Chorley effluent (1 part) and tank liquor (1 part)	Bad.	*Autumn.*—Grey growth half down channel above putrid black mud. Green growth in lower part of channel covered with brown suspended matter. Decomposition of sulphuretted hydrogen gave rise to a yellowish white deposit which checked grey growth. Caddis worm cases abundant. *Winter.*—Grey growth predominating. *April and May.*—Green growth reasserted itself throughout. Grey in first 10 yards only. *Summer.*—Green growth covered with brown deposit throughout.
11. Caterham filter effluent, December, 1907	Very bad.	Grey growth abundant all down the channel. Some green growth along with the grey at the lower end of the channel.
12. Chorley tank liquor alone	Very bad.	*Autumn.*—Grey growth quickly developed, but soon putrefying solids killed it in sluggish parts of channel—elsewhere maintained itself. Mud became covered with dark green growth. *Winter.*—Dark green growth diminished and was less bright. *Summer.*—Dark green growth flourished again and covered with mud, except in upper part of channel where grey growth persisted throughout.

The following points should be noted :—

(1) There is some doubt as to whether the figures of No. 7 represent the liquor which caused the channel to be visibly fouled, and whether some at least of the deterioration in condition should not be ascribed to the disturbance of the green growth caused by cattle. In the latter case the position of this channel should probably be between 5 and 6, *i.e.*, "doubtful." This alteration would be in favour of the general conclusions drawn later.

(2) The position of Channel No. 3, "Caterham effluent," is also open to criticism. The condition of this channel was perfectly good except for a great abundance of green growth which occasionally broke away and, in decomposing, created a nuisance. We have called this condition "doubtful." It certainly could not properly be called "bad," and this is the main point. If it were considered bad, however, the value of our conclusions would suffer materially.

THE AMMONIACAL NITROGEN AND INCUBATOR TESTS.

It will be convenient to take the curve for ammoniacal nitrogen (Chart No. 1) first. On the same chart are given signs representing the broad result of the incubator test (as judged by smell) on each liquid.

It will be seen from this chart :—

(1) That, as regards the "ammoniacal nitrogen," and what we have called the observed general condition of the channels, there is only a very rough correspondence. When a well purified effluent from a strong sewage, on the one hand (No. 3), and a diluted tank liquor on the other (No. 7), are concerned, the relationship breaks down altogether.

(2) That the incubator test (as judged by smell) also shows a broad relationship to general condition of channel, but that it is not sufficiently refined to distinguish between liquors which may produce doubtful, poor, and sometimes bad conditions.

Glancing from left to right across the chart it will be seen that the incubator test gives no sign of deterioration until the general condition of the channel is "bad."

It is clear that neither test could be looked upon as giving, by itself, a reliable indication of the effect which a liquor would produce when flowing undiluted along a ditch, channel or watercourse.

On Chart No. 2 are given side by side the curves for:—

Albuminoid nitrogen.
Oxygen absorbed from $N/8$ permanganate in 4 hours at 80° F.
Dissolved oxygen taken up in 48 hours at 65° F.
Dissolved oxygen taken up in 5 days at 65° F.

The curve for albuminoid nitrogen is plotted on a scale ten times larger than those for the other three tests.

OXYGEN ABSORBED FROM PERMANGANATE IN 4 HOURS AND ALBUMINOID NITROGEN TESTS.

The most noticeable point about the curves for oxygen absorbed from permanganate and for albuminoid nitrogen is the close relationship they bear to one another. This parallelism of the two tests has, of course, been repeatedly noticed by others, but we may usefully refer to it again in order to show that, so far as condition of stream is concerned, there would be little utility in using the two tests together, one of them being sufficient.

As regards the relationship between the observed condition of the channels and the figures of those tests, it will be noted that there is a general rise in the curves from left to right, corresponding to the deterioration in appearance of the channels.

There are, however, six divergencies in each curve, four of these six being, in our opinion, material. Both tests break down as indicators of outside results when effluents, not necessarily well purified effluents, from strong sewages, or when diluted tank liquors, are concerned.

Thus, the Caterham effluent (No. 3) is made to appear worse than the Chorley tank liquor (No. 12), while all the dilutions of the Chorley tank liquor with water (Nos. 2, 4, 5 and 7), are shown as better than the Chorley filter effluent (No. 1).

If either or both of these tests were to be adopted for purposes of a standard by the Commission, cases of hardship might arise with effluents from strong sewages on the one hand, while, on the other, discharges of diluted tank liquor or sewage allowable under the standard might result in offensive conditions of stream or river.

THE DISSOLVED OXYGEN ABSORPTION TESTS.

The curves for these two tests follow each other closely, and in both cases there is more than a general relationship between the analytical figures and condition of channel.

There are marked divergencies at Nos. 3 and 6 in both the 48 hours and the "5 days" curves.

As regards those at 3 and 6 in the "5 days" curve, it will be noted that these are the experiments in which none of the tests are in accordance with the classification arrived at from the observance of actual conditions. The degree of discordance, however, is much less in the "5 days" and "48 hours" curves than in the "oxygen absorbed in 4 hours," the "albuminoid nitrogen" and the "ammoniacal nitrogen" curves.

It would seem, therefore, that the results of any one of the several tests taken separately are liable to fail in indicating the effects on channels produced by effluents from very strong sewages or by diluted tank liquors; but that the results of the dissolved oxygen absorption tests fail in this sense in less degree than those of the other tests.

Before leaving the subject of value of tests it may be useful to give the curves for oxygen absorbed from permanganate in 4 hours and dissolved oxygen taken up in 5 days on another basis, viz.: by drawing each curve on an ascending scale.

Chart No. 3 shows the oxygen absorbed figures arranged in this way, and Chart No. 4 those for dissolved oxygen taken up in 5 days. In each case the scale is the same as in Charts Nos. 1 and 2.

It will be seen from these charts that the test "oxygen absorbed in 4 hours" arranges the experiments in such a way as to place Nos. 7, 8 and 9, which were called "bad," to the left of No. 6, which was called "poor," while No. 3, called "doubtful," and No. 11, which was an indifferently purified effluent, go to the right of No. 12, the Chorley tank liquor.

The test for dissolved oxygen absorption in 5 days, on the other hand, with one exception, only alters on the curve the relative positions of the experiments between the limits of "good" and "doubtful" or "poor and bad."

The exception is No. 7; and doubt has already been expressed as to the proper position of this, some of the objectionable effects observed in the channel being due to disturbance by cattle.

"LIMITING FIGURES OF ANALYSIS."

If either the dissolved oxygen absorption in 48 hours or 5 days was to be adopted as a standard test and a fixed standard arrived at from these channel experiments, it will be seen that the indication is that the figures would require to be

	Parts per 100,000.
For dissolved oxygen taken up in 48 hours at 65° F., not more than -	0·35
For dissolved oxygen taken up in 5 days at 65° F., not more than -	0·55

in order that the condition of the (originally) dry ditch into which the liquor was discharged should not become in any way offensive.

We assume here that the flow along such ditch is a sluggish one.

This would condemn all those liquors used in experiments No. 6 to No. 12 and also the Caterham effluent (No. 3).

It is to be observed that the "limiting figure" thus arrived at for dissolved oxygen absorption in 5 days and that arrived at by the streams observations correspond very fairly (*cf.* Part II., Section 6).

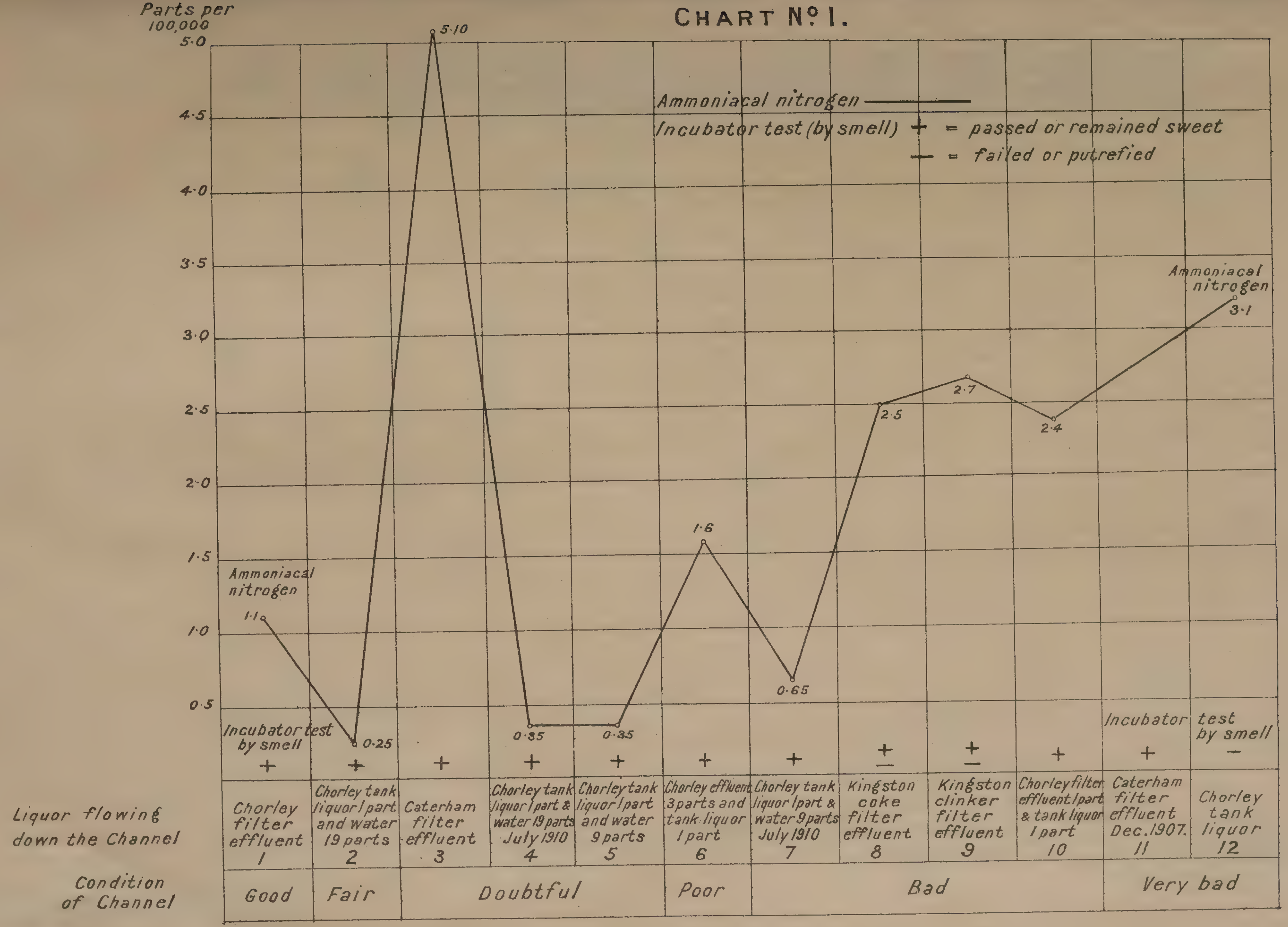
Two general conclusions are thus drawn from the results of these channel experiments :—

(1) The "5 days" dissolved oxygen absorption test is more trustworthy than any other single test in reflecting the condition of a channel receiving sewage effluent or mixtures of sewage effluent with water, and

(2) The "limiting figure" of impurity for an undiluted effluent would be about 0·55 part per 100,000 of dissolved oxygen absorption in 5 days.

It will be seen that these conclusions are in substantial agreement with those arising out of the streams observation proper.

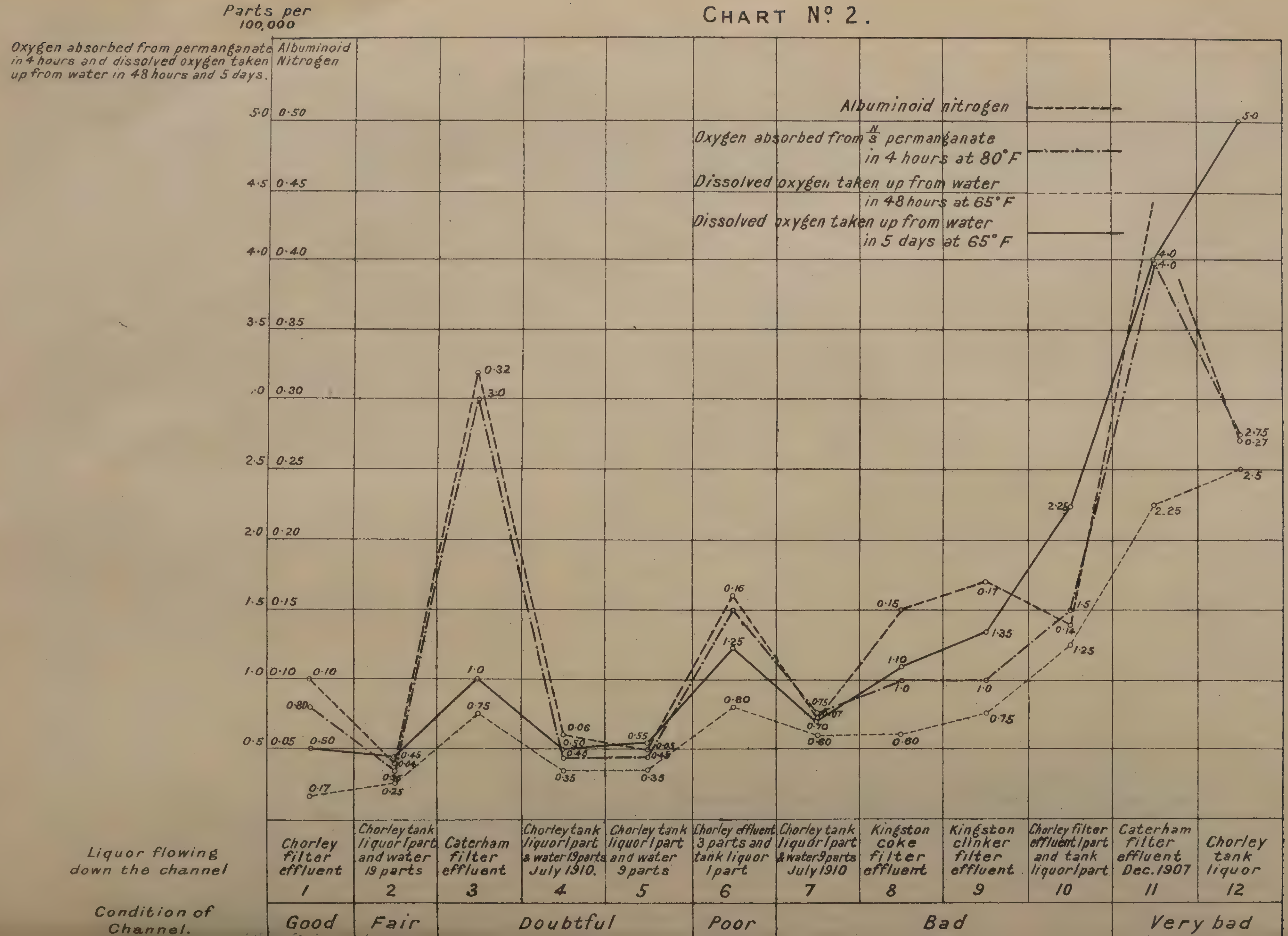
CHART No. 1.

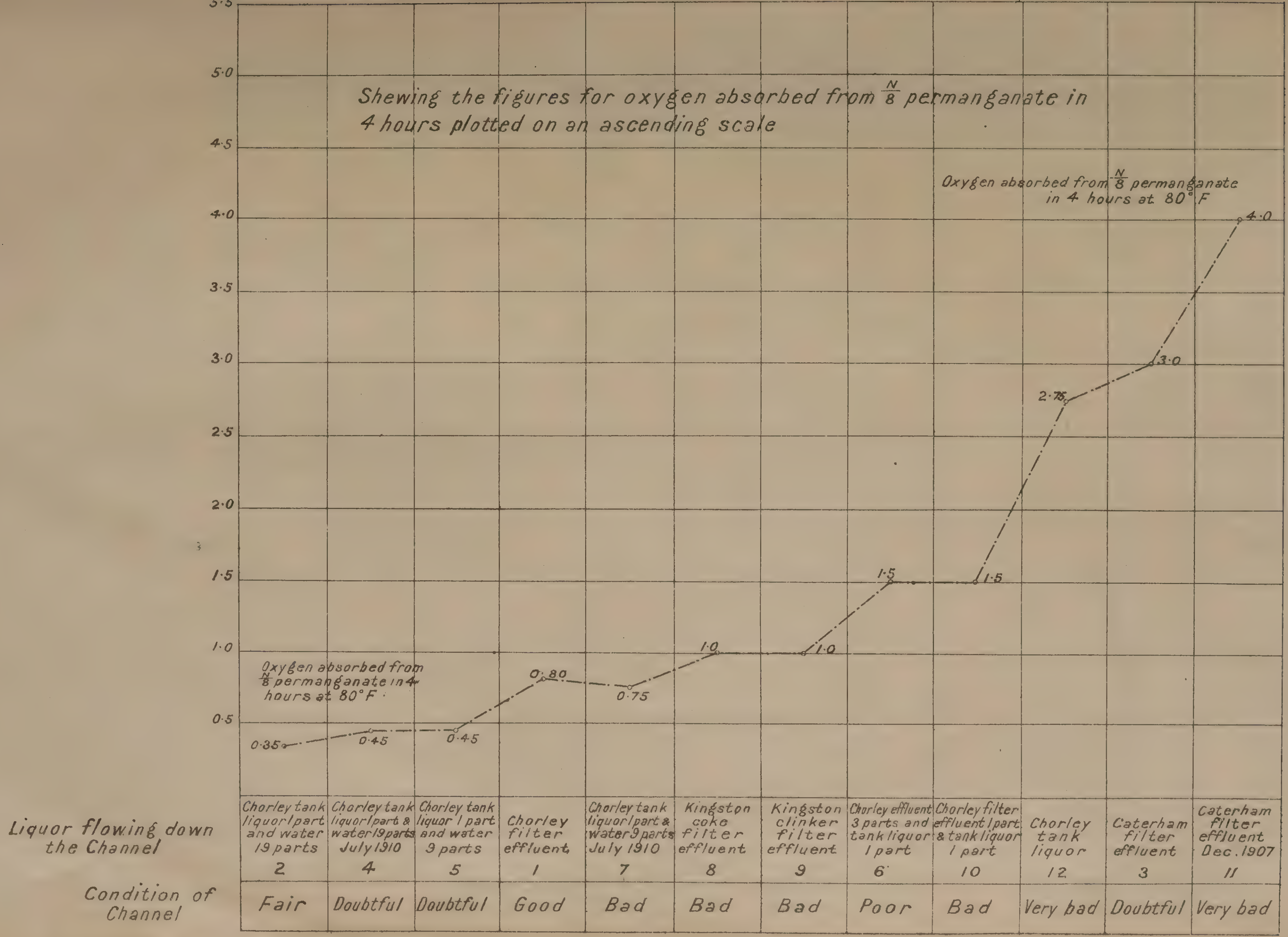


1385. 9302/1903. 1250.7.13

Malby & Sons, Lith.

CHART No. 2.


Parts per 100,000
Oxygen absorbed from permanganate in 4 hours and dissolved oxygen taken up from water in 48 hours and 5 days.
Albuminoid Nitrogen
5·0 0·50
4·5 0·45
4·0 0·40
3·5 0·35
3·0 0·30
2·5 0·25
2·0 0·20
1·5 0·15
1·0 0·10
0·5 0·05
Albuminoid nitrogen
Oxygen absorbed from N/8 permanganate in 4 hours at 80° F
Dissolved oxygen taken up from water in 48 hours at 65° F
Dissolved oxygen taken up from water in 5 days at 65° F
Liquor flowing down the channel
Chorley filter effluent 1
Chorley tank liquor 1 part and water 19 parts 2
Caterham filter effluent 3
Chorley tank liquor 1 part & water 19 parts July 1910. 4
Chorley tank liquor 1 part and water 9 parts 5
Chorley effluent 3 parts and tank liquor 1 part 6
Chorley tank liquor 1 part & water 9 parts July 1910 7
Kingston coke filter effluent 8
Kingston clinker filter effluent 9
Chorley filter effluent 1 part and tank liquor 1 part 10
Caterham filter effluent Dec. 1907 11
Chorley tank liquor 12
Condition of Channel.
Good
Fair
Doubtful
Poor
Bad
Very bad
0·10
0·80
0·50
0·17
0·45
0·04
0·36
0·25
0·32
3·0
1·0
0·75
0·06
0·50
0·45
0·35
0·55
0·05
0·45
0·35
0·16
1·25
0·80
0·75
0·07
0·70
0·60
0·15
1·10
1·0
0·60
0·17
1·35
1·0
0·75
2·25
1·5
0·14
1·25
4·0
4·0
2·25
5·0
2·75
0·27
2·5



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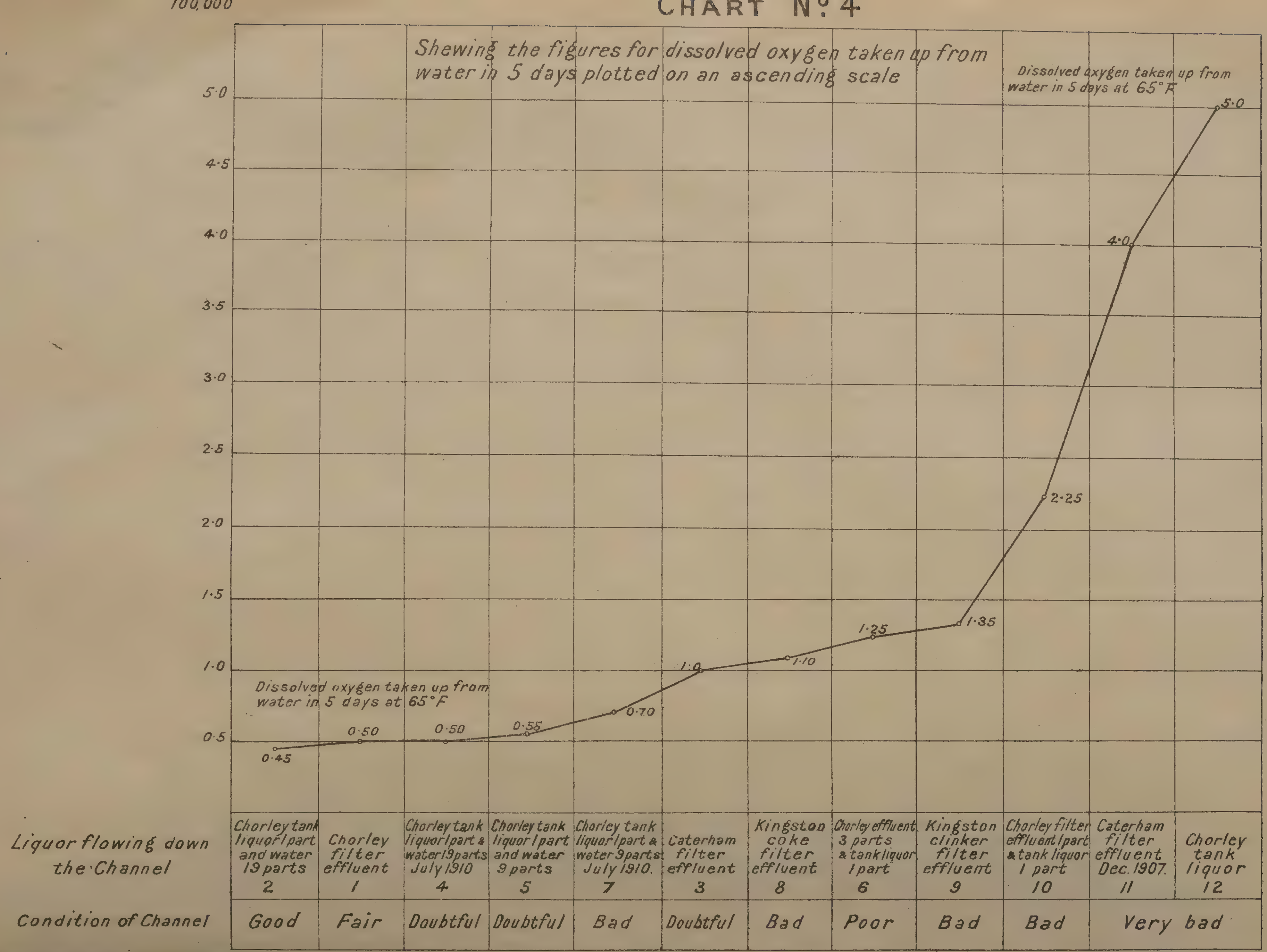

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ROYAL COMMISSION ON SEWAGE DISPOSAL.

NINTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(Including any Liquid from any Factory or Manufacturing Process)

MAY PROPERLY BE ADOPTED.

I. DISPOSAL OF LIQUID WASTES FROM MANUFACTURING PROCESSES.

II. DISPOSAL OF LIQUID AND SOLID DOMESTIC REFUSE IN RURAL AREAS.

VOL. I.—REPORT.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE,
By WYMAN and SONS, Limited, 109, Fetter Lane, E.C.

To be purchased, either directly or through any Bookseller, from
WYMAN and SONS, Limited, 29, Breams Buildings, Fetter Lane, E.C., and
28, Abingdon Street, S.W., and 54, St. Mary Street, Cardiff; or
H.M. STATIONERY OFFICE (Scottish Branch), 23, Forth Street, Edinburgh; or
E. PONSONBY, Limited, 116, Grafton Street, Dublin;
or from the Agencies in the British Colonies and Dependencies,
the United States of America, the Continent of Europe and Abroad of
T. FISHER UNWIN, London, W.C.

1915.

[Cd. 7819.] *Price* 1*s*. 9*d*.

VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath; Our Trusty and Well-beloved Sir Richard Thorne Thorne, Knight Commander of Our Most Honourable Order of the Bath, Medical Officer of the Local Government Board; Our Trusty and Well-beloved Constantine Phipps Carey, Esquire, Lieutenant-Colonel and Honorary Major-General on the Retired List of Our Army; Our Trusty and Well-beloved Charles Philip Cotton, Esquire; Our Trusty and Well-beloved Michael Foster, Esquire, Master of Arts, Professor of Physiology in Our University of Cambridge; Our Trusty and Well-beloved Thomas Walter Harding, Esquire, Retired Lieutenant-Colonel of Our Auxiliary Forces, with Honorary Rank of Colonel; Our Trusty and Well-beloved Thomas William Killick, Esquire; Our Trusty and Well-beloved William Ramsay, Esquire, Professor of Chemistry, University College, London; and Our Trusty and Well-beloved James Burn Russell, Esquire, Doctor of Medicine, Master of Surgery: Greeting!

Whereas We have deemed it expedient that a Commission should forthwith issue to inquire and report:

1. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory, or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities; and

   (2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage;

Now know ye, that We, reposing great trust and confidence in your knowledge and ability, have authorised and appointed, and do by these Presents authorise and appoint, you, the said Walter Stafford, Earl of Iddesleigh, Sir Richard Thorne Thorne, Constantine Phipps Carey, Charles Philip Cotton, Michael Foster, Thomas Walter Harding, Thomas William Killick, William Ramsay, and James Burn Russell to be Our Commissioners for the purposes of the said Inquiry.

And, for the better effecting the purposes of this, Our Commission, We do by these Presents give and grant unto you, or any three or more of you, full power to call before you such persons as you shall judge likely to afford you any information upon the subject of this Our Commission; and also to call for, have access to, and examine all such books documents, registers, and records as may afford you the fullest information on the subject, and to inquire of and concerning the premises by all other lawful ways and means whatsoever.

And We do by these Presents authorise and empower you, or any three or more of you, to visit and personally inspect such places as you may deem it expedient so to inspect for the more effectual carrying out of the purposes aforesaid.

And We do further by these Presents will and ordain that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, and of every matter and thing therein contained, although the same be not continued from time to time by adjournment.

And We do further ordain that you, or any three or more of you, have liberty to report your proceedings under this Our Commission from time to time, if you shall judge it expedient so to do.

And Our further Will and Pleasure is that you do, with as little delay as possible, report to Us, under your hands and seals, or under the hands and seals of any three or more of you, your opinion upon the matters herein submitted for your consideration.

And for the purpose of aiding you in such matters, We hereby appoint Our Trusty and Well-beloved Frederick James Willis, Esquire, to be Secretary to this Our Commission.

Given at our Court at St. James's, the Seventh day of May, One thousand eight hundred and ninety-eight, in the Sixty-first Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. RIDLEY.

WILLIAM HENRY POWER, ESQ., F.R.S.,
To be a Member of the Royal Commission on Sewage Disposal.

VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Well-beloved William Henry Power, Esquire, Fellow of the Royal Society, Medical Officer of the Local Government Board: Greeting!

Whereas We did, by Warrant under Our Royal Sign Manual, bearing date the Seventh day of May, One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved cousin Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, or any three or more of them, to inquire into the treatment and disposal of sewage.

And whereas One of the Commissioners so appointed, namely, Sir Richard Thorne Thorne, has since deceased.

Now know ye, that We, reposing great confidence in you, do, by these Presents, appoint you, the said William Henry Power, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Sir Richard Thorne Thorne, deceased, in addition to, and together with, the other Commissioners whom we have already appointed.

Given at our Court at Saint James's, the Seventh day of February, One thousand nine hundred, in the Sixty-third Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. RIDLEY.

Whitehall, March 18th, 1901.

THE KING has been pleased to issue a Commission, under His Majesty's Royal Sign Manual, to the following effect :—

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland King, Defender of the Faith, to all to whom these Presents shall come, Greeting!

Whereas it pleased Her late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified :

And whereas, in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission ;
The Horse Breeding Commission ;
The Local Taxation Commission ;
The Port of London Commission ;
The Salmon Fisheries Commission ; and
The Sewage Disposal Commission ;

the Commissioners appointed by Her late Majesty, or such of them as were then acting as Commissioners, were, at the late demise of the Crown, still engaged upon the business entrusted to them :

And whereas, We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown :

Now know ye, that We, reposing great trust and confidence in the zeal, discretion, and ability of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissions do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration ; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the fourth
day of March, One thousand nine hundred and one,
in the First Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

THOMAS JOSEPH STAFFORD, F.R.C.S.I.

To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith. To Our Trusty and Well-beloved Thomas Joseph Stafford, Esquire, Fellow of the Royal College of Surgeons of Ireland, Medical Commissioner of the Local Government Board for Ireland : Greeting !

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, to be Commissioners to inquire into the treatment and disposal of Sewage.

And whereas, one of the Commissioners so appointed, namely, Our Trusty and Well-beloved Charles Philip Cotton, Esquire, hath humbly tendered unto Us his resignation of his appointment as one of the said Commissioners :

Now know ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Thomas Joseph Stafford, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Charles Philip Cotton, resigned, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of May, One thousand nine hundred and two, in the Second Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

REGINALD ARTHUR TATTON, ESQUIRE,

To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R. & I.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith, To Our Trusty and Well-beloved Reginald Arthur Tatton, Esquire, Greeting !

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May, One thousand eight hundred and ninety-eight, appoint Commissioners to inquire into the treatment and disposal of Sewage.

And whereas, a vacancy has been caused in the body of the Commissioners appointed as aforesaid by the death of Major-General Constantine Phipps Carey, C.B.

Now know ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Reginald Arthur Tatton, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Constantine Phipps Carey, deceased, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of January, One thousand nine hundred and seven, in the Sixth Year of Our Reign.

By His Majesty's Command,
(Signed) H. J. GLADSTONE.

Whitehall, May 30th, 1910.

THE KING has been pleased to issue a Warrant under His Majesty's Royal Sign Manual to the following effect :—

GEORGE R. & I.

George the Fifth, by the Grace of God, of the United Kingdom of Great Britain and Ireland, and of the British Dominions beyond the Seas King, Defender of the Faith, to all to whom these Presents shall come. Greeting!

Whereas it pleased His late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified :

And whereas, in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission ;
The Horse Breeding Commission ;
The Sewage Disposal Commission ;
The Poor Laws Commission ;
The Tuberculosis Commission ;
The Canal Communication Commission ;
The Mines Commission ;
The Welsh Church Commission ;
The Coast Erosion and Afforestation Commission ;
The Vivisection Commission ;
The Land Transfer Acts Commission ;
The Ancient Monuments (Wales and Monmouthshire) Commission ;
The Ancient Monuments (England) Commission ;
The Trade Relations between Canada and the West Indies Commission ;
The Selection of Justices of the Peace Commission ;
The Divorce and Matrimonial Causes Commission ;
The University Education in London Commission ; and
The Brussels, Rome and Turin Exhibitions Commission ;

the Commissioners appointed by His late Majesty, or such of them as were then acting as Commissioners, were at the late demise of the Crown, still engaged upon the business entrusted to them :

And whereas, We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown :

Now know ye, that We, reposing great trust and confidence in the zeal, discretion, and ability, of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissioners do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration ; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents, shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the twenty-sixth day of May, One thousand nine hundred and ten, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) R. B. HALDANE.

FREDERICK JAMES WILLIS, ESQ.,
To be a Member of the Royal Commission on Sewage Disposal.

GEORGE R. & I.

George the Fifth, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith: To Our Trusty and Well-beloved Frederick James Willis, Esquire, Barrister-at-law, one of the Assistant Secretaries to the Local Government Board: Greeting!

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh day of May, One thousand eight hundred and ninety eight, appoint Commissioners to inquire into the treatment and disposal of Sewage:

Now know ye, that We, reposing great confidence in you do by these Presents appoint you the said Frederick James Willis, sometime Secretary to the said Royal Commission, to be an additional Commissioner for the purposes aforesaid.

Given at Our Court at Saint James's the Twentieth day of July, One thousand nine hundred and ten, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) W. S. CHURCHILL.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

NINTH REPORT.

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ROYAL COMMISSION ON SEWAGE DISPOSAL.

NINTH REPORT.

To the King's Most Excellent Majesty:

May it please Your Majesty:

We, your Commissioners, being appointed to enquire into the methods of disposing of sewage and trade effluents, humbly submit a further Report, as follows:

I. On the disposal of liquid wastes from manufacturing processes; and

II. On the disposal of liquid and solid domestic refuse in rural areas.

I.—THE DISPOSAL OF LIQUID WASTES FROM MANUFACTURING PROCESSES.

Introduction.

1. Our terms of reference required us to report upon the methods of treating and disposing, not only of domestic sewage, but also of any liquid from any factory or manufacturing process.

Disposal of Trade Waste unmixed with Sewage.

2. In previous reports we have dealt with the treatment and disposal of domestic sewage alone and of domestic sewage mixed with liquid waste from factories, and we have now to consider the disposal of liquid trade waste unmixed with domestic sewage.

3. The trades or manufacturing processes with which we are concerned require the use of water in considerable quantity, and the problem with which we have to deal is the proper treatment or disposal of the water after use.

Different kinds of Trade Waste.

4. In some cases, such as in tin mining or stone quarrying, the water is used merely as a mechanical carrier, with the result that, apart from the addition of much suspended matter, its quality is not materially affected. In other cases, where it is used as a solvent, as, for instance, in wool washing, the dissolved impurities are very great, and the water is rendered far more foul and polluting than strong domestic sewage. Again, other manufacturing processes give rise to liquid wastes which are highly objectionable on account of the corroding or poisonous nature of the chemicals which they contain.

5. The character of the waste liquor varies with each trade, and frequently with different branches of the same trade, but, speaking generally, it may be said that liquid trade waste is of a highly objectionable and polluting nature. As regards the quantity, it is to be observed that in the manufacturing districts the volume of waste liquor discharged from a single factory during a working day of 10 to 14 hours may amount to as much as 500,000 gallons, equivalent to the daily volume of domestic sewage of a town with a population of about 17,000 persons.

6. These general facts and the filthy state of many rivers and streams in the manufacturing districts show clearly the necessity for laws regulating the purification or disposal of liquid trade wastes.

Discharge into sewers recommended where practicable.

7. As we pointed out in our Third Report, the most effective, as well as most economical, means of protecting our rivers from damage due to the discharge of trade liquids is the treatment of these liquids, when practicable, at the sewage works of the local authority, and we accordingly recommended that the law should be altered so as to give manufacturers the right to discharge their waste liquors into the sewers subject to certain conditions. We desire to repeat and emphasize this recommendation, which was in the following terms:—

> "22. We are therefore of opinion that the law should be altered so as to make it the duty of the local authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and that the manufacturer should be given the right, subject to the observance of certain safeguards, to discharge trade effluents into the sewers of the local authority if he wishes to do so.
>
> "We do not think it possible to provide by direct enactment what these safeguards should be. In each district it would probably be desirable that the local authority should frame regulations which should be subject to confirmation by a Central Authority. In most cases, however, these regulations could provide definite standards for the different manufacturers as regards preliminary treatment, and it appears from the evidence that the manufacturers would much prefer to have standards to work to.
>
> "Power to vary the standards or to dispense with them altogether in special cases would be necessary.
>
> "23. Although the duty of receiving trade effluents should, we think, be imposed on the local authority, cases may arise in which they should be wholly or partially relieved of it.

"For example, we find that in some instances the effluent discharged from the manufactory is of a composite character, the greater part of which might with advantage be easily dealt with by the manufacturer if it were kept separate. In such cases we think the manufacturer would generally be willing to adopt this course, but provision is necessary for those cases in which the local authority and manufacturer could not agree.

"Further, although we have received no conclusive evidence to show that there are trade effluents which could not be purified by the local authority, we do not deny the possibility of such cases arising.

"And it is possible that in some cases as, for example, of a large manufactory being newly established in a small district, it might be necessary to relieve the authority of the obligation to treat the trade effluent or to enable them to exact some special contribution from the manufacturer not only for the cost of treatment but also towards capital expenditure.

"24. It is obvious, therefore, that some tribunal will be required for settling the differences between the local authority and the manufacturer, and for relieving the local authority in exceptional cases either wholly or partially of their obligation to provide sewers and disposal works of sufficient capacity for trade effluents as well as ordinary sewage."

General Legislation required.

8. Unfortunately effect has not yet been given to these recommendations. Most of the larger local authorities do in fact receive into their sewers a large number of trade effluents of small volume without conditions, and in some cases on special conditions; and this policy has been useful in assisting the trades of their districts without materially increasing the difficulties of sewage treatment.

9. On the other hand, most small authorities show considerable reluctance to receive trade effluents into their sewers at all. We think that this reluctance may be partly due to the fact that in many cases the cost to the local authority of treating trade effluents is considerably in excess of the amount received in sewage rates from the traders; indeed, we have had evidence of cases in which the cost of treatment exceeds the rates paid by the traders for all purposes. In our Third Report we recommended that traders discharging into sewers should if possible comply with certain conditions as to preliminary treatment which would facilitate the final treatment of their effluents, but that no special charge should be made upon them unless for any reason they were unable to comply with those conditions. We added, however, that "power should also be granted to make a special charge even when preliminary treatment is adopted, when there are exceptional circumstances as regards volume, quality, or otherwise."

10. Since the issue of that Report in 1903, a few local authorities have, in the absence of general legislation, obtained powers under local Acts for dealing with trade effluents. In these Acts power is given to the local authority to make a charge upon the trader when the regulations in regard to preliminary treatment, control of flow, etc., are not complied with, or where there are such exceptional circumstances as are indicated above. In one of the Acts. however, the power to charge is not so restricted. Our own additional experience and the further evidence which has been laid before us indicate that it may be desirable that local authorities should have a general power to make a charge, provided that the charges were lower in the case of effluents which had been subjected to preliminary treatment in accordance with the regulations. As we recommended in our Third Report, any such charges should be fixed by agreement between the manufacturer and the local authority—or in default of agreement by the Rivers Boards, subject to appeal by either party to the Central Authority. Further, we would repeat our recommendation that the power to make a charge should extend to cases in which connection with the sewers already exists, subject to the terms of any agreement under which a manufacturer may have purchased the right to discharge his trade effluent into a sewer.

In many cases trade waste must be treated separately.

11. But notwithstanding a general extension of the system under which purification of trade wastes is undertaken by local authorities, there will remain many cases in which manufacturers must remain responsible for the treatment of their own trade liquids.

For example, manufacturers who take water from streams may be infringing riparian rights by turning their waste liquids into sewers. Again, there may be no sewers available, or the sewers may be of insufficient capacity for the reception of the liquors, or the efficiency of the sewage works may be seriously impaired by the accession of large volumes of trade wastes.

It is with such cases as these that we have now to deal.

Complex nature of the problems.

12. The subject is one of very great complexity, requiring further time and experiment for its elucidation. In many cases we cannot furnish complete solutions of the several problems that arise; we can only indicate the lines on which, in our opinion, the appropriate solutions should be sought.

Requiring independent investigation.

13. In one or two instances, where immediate action by us seemed to be called for in the interest of the river or trade, we have undertaken special experiments with advantageous results, but to do this for all liquid trade wastes would involve prolonged scientific

research, which could best be carried out by a permanent department, the constitution of which we have repeatedly recommended.

Manufacturers cannot be expected to discover means of purification

14. It is unlikely in most cases that manufacturers will be able or willing themselves to undertake the scientific investigations which are required in order to discover the best means of rendering harmless the liquids which are produced by their particular trade. As the law stands, indeed, it is not to their interest to do so, seeing that under Section 6 of the Rivers Pollution Prevention Act, 1876, proceedings cannot be taken against manufacturers unless the Local Government Board are satisfied, *inter alia*, that "means for rendering harmless the poisonous, noxious or polluting liquids proceeding from the processes of such manufacturers are reasonably practicable and available under all the circumstances of the case." Hence, in the case of manufacturing waste of which no practicable means of treatment are known, the manufacturer who is at pains to discover such means will no doubt confer a benefit on the community, but in so doing will render both himself and others connected with the same trade liable not only to the expense of constructing purification works, but also to the risk of proceedings from which they would otherwise be exempt.

although in some instances this expenditure may be profitable.

15. It is true that in some cases a manufacturer may by adopting means of purification derive direct and material advantage from his expenditure. Thus, when water has to be purchased, the treatment of his liquid waste may render it suitable for further use as water in the process of manufacture, and so lead to substantial economies. Or, again, treatment of waste liquids may result in the recovery either of a large proportion of the material which it is the primary object of the industry to secure, or of separate by-products which have a commercial value. Thus, in the dyeing industry the effluent after purification can frequently be used again with advantage and economy; at tin mines and china clay works considerable quantities of the minerals are obtained from further treatment of the washing waters; in various woollen industries the recovery of grease may recoup a part, or even the whole, of the cost of purification; while by some coal-washing processes both loss of coal and waste of water are prevented. At the same time it has to be borne in mind that the interests of manufacture are not the only consideration on which the demand for improvement rests. To meet this demand some stimulus other than prospect of profit will be required.

Distinction between industrial and other districts under existing law.

16. By Section 6 of the Rivers Pollution Prevention Act, to which we have referred above, it is provided that the Local Government Board

> ". . . shall not give their consent to proceedings by the sanitary authority of any district which is the seat of any manufacturing industry unless they are satisfied . . . that no material injury will be inflicted by such proceedings on the interests of such industry."

From the principle embodied in this enactment we do not dissent. In the special investigations which we have conducted we have considered the question of cost from this point of view, and we think that the primary object of future experiments to be carried out by the central authority should be to show, not that purification can be carried out with profit or without loss to the manufacturer, but that the cost should not be so great as to inflict material injury upon the industry.

17. This principle is, however, qualified by the words quoted above: "in any district which is the seat of any manufacturing industry." These words are important, as indicating that in industrial centres the special interests of manufacturers should be regarded with an indulgence which they would not receive in other places. The framers of the Act of 1876 recognised that in such centres the interests of the community are largely bound up with the interests of the manufacturers, and that to demand from manufacturers costly schemes of purification might injure the community without securing any corresponding improvement in the character of their river, which was already materially, if not hopelessly, impaired by its environment. On the other hand, it would be clearly inequitable if in a sparsely populated district a manufacturer, with a view to obtaining free of charge a supply of clean water, were to set up his works on the banks of a stream, and were to be entitled to discharge polluting liquids into the stream on the ground that the cost of purification works would inflict material injury upon his industry.

Condition of rivers in industrial centres.

18. We may, however, point out that this distinction between industrial and other districts, while it is intended to prevent the extension of industrial pollution to fresh districts, may also tend to perpetuate the conditions which prevail in manufacturing centres. The problem presented by the rivers which flow through such centres has become so complex and of such large dimensions that under present conditions measures of purification can be expected to do little more than act as a palliative of the grosser forms of pollution.

The cost of such measures is felt, but their benefits are negative rather than positive in character. It is necessary that means of purification should at once be more efficient and more generally enforced if their cost is to be compensated by material advantages.

19. For example, the advantage to a riparian manufacturer of being able to obtain clean water from the river is obvious; but owing in great measure to the difficulty of administering the existing law, the condition of many rivers is such that their water is valueless for manufacturing purposes, and the prospect of restoring by remedial measures any serviceable degree of purity to such rivers must needs appear so remote as to deter manufacturers from spending more money than they are compelled on purification works which are of no direct benefit to themselves and of scarcely appreciable benefit to others. But if a more efficient, albeit perhaps more costly, system were in force, manufacturers would be able to save large sums which they are now compelled to spend in obtaining clean water, and would thus have a direct interest in securing the purity of their common source of supply.

20. In a district which is not the seat of a manufacturing industry we have said that the present law is intended to prevent the extension of industrial pollution. We do not find, however, that the operation of the law has proved efficient in this regard. In such districts there are various interests which in our opinion need further protection. Apart from considerations of public health, the interests of fishing and of agriculture, as well as the amenities of the river are liable to be adversely affected by pollution. We think it right to draw special attention to the protection of fishing, both in tidal and non-tidal waters, not only because in many cases it is an important industry but because it is peculiarly liable to serious injury from pollutions which, under present conditions, neither those concerned in the industry nor the authorities who are charged with the duty of dealing with pollution have adequate power to prevent.

21. The Royal Commission on Salmon Fisheries, after discussing the possible constitution of Fishery Boards on similar lines to the Watershed Boards recommended by us in our Interim Report, say on p. 12 of their Report:

Cd. 1188, 1902.

> "It might even be possible to create a Watersheds Board of still larger authority. There are three great subjects for all of which, in our opinion, the watershed is the proper administrative area, *i.e.*, pollution, water supplies, and fisheries. If it were possible to give adequate representation to all the interests concerned in one body, we should have a Board of great influence capable of interfering authoritatively in any matter affecting the district, while by the formation of separate Committees the administration of each of the subjects above named might be left in the hands of representatives best qualified to carry it on. The Government alone can decide whether anything of this kind is practicable, but we have thought it right to make the suggestion to mark our sense of the interdependence of the different interests specially concerned in the preservation of the purity of our rivers."

Again on p. 46 of the same Report they say:—

> "We have deemed it unnecessary to pursue this investigation in greater detail because of the parallel inquiry which is being conducted by the Royal Commission on Sewage Disposal. The Commissioners in their interim Report, dated July 12th, 1901, have dealt with the question of 'what means should be adopted for the better protection of our rivers,' and have recommended a single authority for each watershed under a Supreme Rivers' Authority. This recommendation we unhesitatingly adopt and cordially support, and on p. 12 we have suggested that the same authority might administer fishery matters in England and Wales. But this proposal would not so easily be reconciled with the Scottish system, and may not be accepted for England and Wales, and, accordingly, we desire to state our strong opinion that the Local Fishery Board within its district should have a distinct and acknowledged right of drawing attention to any pollution which is injurious to the fishings which is due to an effluent not up to the standard of purity determined within their districts, and the assurance that action will be taken upon such complaints by the Watersheds Board, or any other authority entrusted with the duty of preventing the pollution of rivers."

22. Finally on pp. 62 and 63 the Commission sum up their recommendations (in regard to pollution) as follows:—

> "In England and Wales we should prefer to see the administration in the hands of a powerful Watersheds Board appointed to deal, not only with salmon and freshwater fisheries, but with all questions of pollution and abstraction of water. . . . In Scotland we do not consider it necessary to introduce large changes. . . . On the other hand our understanding is that in both countries the Watersheds Board proposed by the Sewage Disposal Commission will undertake on behalf of the Local Fishery Boards all questions arising out of the pollution, and we hope the abstraction, of water. . . .
>
> "We therefore concur in the recommendation of the Sewage Disposal Commission for the creation of a Watersheds Board under a Supreme Rivers Authority in those waters, on the understanding that the recommendations of the Sewage Commission on the methods to be adopted for the purification of rivers and estuaries will cover the requirements of the fisheries, and that provision will be made for the protection of fishery interests by the Watersheds Board."

Fourth Report paragraphs 47 and 48.

23. In our Third Report we made further recommendations in regard to the formation of Rivers or Watershed Boards throughout the country, and in our Fourth Report, which dealt more particularly with tidal waters, we recommended that the necessary power of control over the pollution of such waters should be vested in the Rivers Boards, and that Sea Fisheries Committees should be empowered to appoint one or more representatives on Rivers Boards having tidal waters under their jurisdiction. We also supported generally the view of the Salmon Fisheries Commission that if practicable the powers of Salmon Conservators and other similar bodies should be transferred to the Rivers Boards. In that event the duty of protecting fisheries should be expressly imposed on the Rivers Boards, who should be armed with such extended powers as may be necessary to deal with pollution in the interest of fishing as well as in the interests of public health.

We desire to repeat and emphasize the recommendation that fishery interests whether in tidal or inland waters should be represented on the Rivers Boards having control over such waters. In districts where it may not be necessary that a Rivers Board should be set up, we think that the County Council should be clothed with any powers necessary for carrying out the duties of a Rivers Board, including the power to co-opt representatives of the various fishing interests.

24. We think, then, that both in industrial and other districts legislation can do much to reduce or prevent the pollution of rivers. The main objects of such legislation should be to secure (1) more general reception of trade effluents into sewers; (2) improved supervision of rivers; and (3) prosecution of scientific research.

With the first of these objects we are not at the moment concerned. We have dealt with the subject at length in our Third Report, and we only refer to it here for the sake of emphasizing our opinion that if the bulk of trade effluents were received into sewers, the magnitude of the problem would be so greatly reduced that a valuable incentive would be supplied for attacking the remaining difficulties.

In the same Report we have considered the machinery by which improved supervision of our rivers could be secured, viz., the formation of Rivers Boards throughout the country, acting under a Central Authority; and in a later section of the present Report we shall indicate in greater detail what should be the functions of those bodies in relation to the discharge of manufacturing wastes directly into streams.

Research by Central Authority.

Third Report: Paragraph 45.

25. As regards scientific research we would urge that the investigations which have been instituted by river authorities, by private individuals, and in some cases by ourselves, should be continued and extended by the Central Authority, whose constitution we have repeatedly recommended. We have already suggested that the staff of the Central Authority should include a chemist, an engineer, and a bacteriologist, all with special qualifications, and that it should be equipped with a laboratory; and we think that the function of discovering the most efficient and economical means of treating the different classes of trade liquids would form a most important branch of the duties of such an authority.

Chief difficulty one of cost.

26. The problems to be solved are very largely financial. It must be admitted that thorough purification of liquid trade waste is frequently very costly, and that if it were enforced upon all manufacturers indiscriminately in the present state of our knowledge a vast sum of money might be expended without commensurate benefit to rivers. Large sums of money have already been spent in this way, and although the expenditure has improved the condition of rivers, we cannot help noticing that substantial amounts have been wasted through want of technical knowledge. For example, large settling tanks have had to be erected at some works owing to the wasteful and unscientific method of washing adopted. The same cleansing effect could frequently be produced with a much smaller volume of water, with a consequent saving, apart from economy of water, in the expense of constructing settling tanks.

General scope of present inquiry.

27. To pave the way for further investigations we have made a general preliminary survey of the ground to be covered, and have indicated, where possible, the lines on which we think advance should be essayed. To this end we have made some enquiry into the character of the different trade effluents. We have caused average samples to be drawn and analysed by our officers, who have also carried out purification experiments on a laboratory scale with certain trade effluents and on a large scale with two or three others. The results are given in later sections of this report, but we may make some general remarks as regards their material bearing.

General characteristics of trade **effluents. Suspended matter.**

28. They show that all the more important trade wastes are liquors which contain a very considerable quantity of suspended matter, and most of them take up a large amount of oxygen when submitted to the "5 days dissolved oxygen absorption" test.

29. We have made no experiments ourselves, and we know of none made by others, which show that the polluting power of a trade liquor of given oxygen-absorbing strength is equal to that of a domestic sewage liquor of the same oxygen-absorbing strength.

Probably the effect of the discharge of not a few trade liquors into a river differs somewhat from the discharge of domestic sewage, for their rate of absorption of oxygen may be very slow to begin with, being delayed, no doubt, by the inhibitory action of some substances in solution, and may only reach its maximum in two or three days, while with most sewages and sewage liquors the maximum rate of oxygen absorption is reached within 24 hours. On the other hand there are trade wastes which closely resemble sewage as regards the rate at which they take up oxygen from water, some indeed, which would have a more immediate effect of this kind on the river.

There are, too, certain trade wastes whose organic matter is mainly carbonaceous, which may take up oxygen from water rather rapidly without giving rise to nuisance from smell when the oxygen becomes exhausted, or nearly so.

Absence of much Nitrogen.

30. Again, the quantity of nitrogen contained in many trade liquors is relatively small, and as other plant food constituents, such as phosphorus and potash, are doubtless present only in minute quantities, if at all, if follows that such trade liquors are unlikely to cause excessive vegetable growths of any kind in rivers. Indeed, seeing that they sometimes contain certain poisonous substances, they may destroy or inhibit vegetation in rivers, and so diminish important self-purification agencies. The poisoning of aquatic insects, worms, or of other forms of animal life, etc., is another very important effect which must be borne in mind, especially in relation to fish life.

Destruction of Vegetable and Insect Life.

Acidity, Alkalinity and Hardness.

31. Many trade liquors, moreover, are strongly coloured, or acid, or alkaline, or they are excessively "hard," and in such cases they may very materially impair the quality of the river water for manufacturing purposes.

Certain classes of trade liquors would have to be purified to something like the same extent as a domestic sewage if nuisance was not to be caused in the stream receiving them; and, in addition to this, they would have to comply with standards for "acidity," "alkalinity," "hardness," and poisonous metals. In other words, they would require not only full biological treatment, but special preliminary treatment in addition.

Sufficient purification not yet possible in some cases.

32. It is practicable to purify at reasonable cost some trade waste liquors to an extent sufficient to prevent injury to the stream, but as regards others we know of no examples showing that this is possible in the present state of our knowledge.

33. Before making any suggestions as to the extent to which we think purification should be carried in any particular case, we proceed to give a detailed account of the chief trade processes with which our inquiry is concerned, of the liquid wastes which are caused by these processes, and of the measures which have been or could be adopted for purifying the wastes before their discharge into streams.

We think it important to make it clear that the examples of purification works cited comprised the best that we could find after consultation with the Rivers Board or County Council concerned. In each case we satisfied ourselves, before drawing our own samples, that the plant was being worked with proper care and under normal conditions.

Groups of Trade Wastes.

34. We propose to classify these liquid wastes in three groups, as follows :—

(1) Those which are polluting by reason of the suspended matter which they carry with them;

(2) Those which are polluting mainly because of the suspended matter which they carry with them, but also to a considerable extent because of the dissolved impurities which they contain; and

(3) Those which are polluting mainly because of the dissolved impurities which they contain.

We have thought it desirable in referring to the various works and factories which have been visited in connection with our inquiry, to omit all mention of names, and to distinguish them by numbers only. Our gratitude is owing to those manufacturers who, at no small trouble, and in many cases expense, have afforded us very valuable facilities in pursuing our investigations.

A summary of our conclusions and recommendations will be found on pages 165–177.

SECTION I.

LIQUID WASTES WHICH ARE POLLUTING BY REASON OF THE SUSPENDED MATTER WHICH THEY CARRY WITH THEM.

35. In certain industrial operations water is used merely as a means of mechanical transport, and not because of any solvent action which it may have on the material dealt with. These operations are carried out mainly in connection with metalliferous mining, coal mining and the quarrying of stone and of china clay. In connection with metalliferous mining, water is used for the separation of the valuable mineral from the rocky matrix with which it is found associated; in coal-washing, the object is to remove shale, pyrites and dirt, and to separate the fine coal into various grades; in the quarrying of china clay, to remove silica and mica, and in stone quarrying and polishing, to remove fine grit and dust.

In every case the water after use carries with it much suspended matter, but it contains, as a rule, little more matter in solution than it did before use.

36. The Royal Commission appointed in 1868 to inquire into the best means of preventing the pollution of rivers, dealt fully with this class of waste liquid (Rivers Pollution Commission, Fifth Report, Vol. I., 1874).

They found that serious injury to streams arose through the discharge of suspended matter from mines.

In Section A., Descriptive, 1., p. 3, Fifth Report, Vol. I., they make the following general statement :—

> " In describing the nature and extent of injury to rivers caused by mining operations it will be convenient to make the following classification of sources of pollution :—
>
> 1. Pollution by collieries and coal-washing.
> 2. Pollution by iron mines.
> 3. Pollution by lead, zinc, copper and arsenic mines.
> 4. Pollution by tin mines.
> 5. Pollution by manganese mines.
> 6. Pollution by baryta mines.
> 7. Pollution by china clay works.
>
> Of the seven kinds of mines here enumerated, the first, second, fifth and seventh contribute polluting matter which, though in many cases very unsightly, is, as a rule, not directly injurious to health, but the waste matters discharged into rivers from the third, fourth and sixth are frequently of a character to produce injury to the health of persons using the water for domestic purposes, or of cattle grazing in fields which have been flooded by water so fouled. The polluting matters are nearly always in suspension and scarcely ever in solution; and as water polluted by mining refuse is almost invariably too muddy and repulsive in appearance to be used for drinking, it very rarely happens that injury to health arises in this way; indeed, we have not become acquainted with even a single case of alleged injury to human health and with very few cases of injury to animals, by the drinking of water fouled by any of the branches of the mining industry. It must be added, however, that many of these refuse matters are very destructive to fish."

In Section B., Remedies, 2, p. 39, of the same Report, the Commission say :—

> " In treating of the pollution of the streams in the Mersey and Ribble basins in our First Report we recommended (First Report, Mersey and Ribble Basins, Vol. I., p. 130) that any liquid containing in suspension more than 3 parts by weight of dry mineral matter in 100,000 parts by weight of the liquid should be deemed polluting and inadmissible into any stream. That Report referred chiefly to the sewage of towns, the calico and silk industries, and chemical works; and we found that all the polluting liquids arising from these sources could easily and without any detriment to trade or to the public health be so purified as to prevent their transgression of the standard of purity just quoted. When our investigations were afterwards extended to the waste liquids arising from the various branches of the woollen trade, and the flax, linen and jute industries, from paraffin and petroleum works, and from sugar refineries, alcohol distilleries and starch factories, we still found that the enforcement of the same standard would cause no 'serious injury to such processes and manufactures.' But soon after commencing our inquiries into the mining operations carried on in this country, it became evident to us that this standard could not be enforced against polluting liquids from mines without inflicting undue hardship upon these branches of industry."

After giving the results of some laboratory experiments upon the fractional subsidence of mine polluted river muds and waste liquids from various mines, the Commission make their recommendation as to treatment in the following words (p. 43) :—

> " The results of these experiments point to a very simple and inexpensive, though we fear unavoidably imperfect remedy for the chief form of mining pollution. We have already proved, see pages 15, 16, 17, 19, 25 and 29, that, in addition to arsenic and solid rubbish wilfully shot into running water, the sole polluting agent discharged into rivers from metalliferous mines is matter, chiefly mineral, in suspension,

and we find, as the result of our investigations, that an efficient remedy for this single form of fouling would leave nearly all the rivers now suffering from metalliferous mines in their pristine condition of purity. Nay, our analyses have over and over again demonstrated that, this suspended matter once removed, the water is left even purer than it was before the pollution occurred, the deposited mineral mud having carried down with it a considerable proportion of the organic matter which was previously in solution.

Unfortunately, the extent of the application of this remedy which we are prepared to recommend is not sufficient to render the purification as complete as our suggested standards require. It would, in our opinion, seriously interfere with the mining industry of this country, if a standard relating to suspended mineral matter, so stringent as that which has been found easily practicable in other branches of industry, were enforced against discharges from mines. Whilst we believe, however, that subsidence as complete as desirable, could not practically be applied to such discharges, our inquiries into this matter show that a very moderate amount of settlement, say six hours, would remove a very large proportion of the noxious matters from the water. Our determinations detailed above show that this moderate amount of subsidence would, if enforced, reduce in many cases the evils at present so loudly complained of to less than one-hundredth of their present amount. Indeed, it may be reasonably expected that, so far as silting up, and the destruction of fish ova by the deposition of mud upon the spawning beds, are concerned, the relief to our rivers would generally be very much greater than is indicated by the above fraction, for the residual matter still in suspension in the partially clarified water would have little tendency to deposit in the lower parts of the stream. It would, in all probability, remain in suspension and be finally carried out to sea, leaving the gravelly spawning beds free from slime, and allowing but little, if any, deposition of mine mud upon lands liable to submersion in time of flood.

For the realisation of the salutary result, however, it is absolutely necessary that the subsidence of six hours should be of a *bona fide* character. Little of the advantage just recorded would be gained if a stream, however slow, were allowed to flow through the settling ponds. We find that subsidence is enormously hindered by even the slightest movement of the body of water in which it is taking place; and hence it is that, although we have seen in numerous cases subsidence ponds provided in connection with dressing floors, ostensibly for the purpose of preventing river pollution, in no single instance has the result been satisfactory, owing to the universal neglect of this precaution.

We desire it, therefore, to be distinctly understood that no subsidence of waste mine water is worthy of the name, which does not include perfect rest of the water during the operation. Efficiently to carry out the remedy which we recommend, it will be necessary to provide storage for at least as much muddy water as is produced in eighteen hours. This storage must be divided into three ponds, two of which should be alternately used whilst the deposit in the third is being drained, dug out, and removed to a position from which it cannot be washed into the neighbouring streams. The alternating ponds should be used in the following manner:—

The muddy water is to be run into pond No. 1 for six hours, the exit being completely closed; the stream is then to be turned into pond No. 2 for the same length of time. After five hours of perfect rest the discharge of pond No. 1 may be commenced by lowering a wide sill, so as to allow the surface water to the depth of, say, 3 inches, to flow away. The sill is to be gradually lowered so as to complete the discharge within an hour, and care must be taken that it is not so far depressed as to permit the escape of any of the deposited mud. The sill being again raised, the pond is ready to receive a second charge of muddy water, whilst the contents of pond No. 2 are undergoing subsidence. The ponds may be of any depth, but in order to insure adequate subsidence of their contents, the depth of water run off in discharging them ought not to exceed 5 feet."

37. Since the issue (in 1874) of that Report considerable changes have taken place in connection with the mining industry. Many metalliferous mines which were then worked have been shut down, with corresponding diminution of the pollution of rivers from those kinds of mining waters liable to cause the more serious injury to fish and to agricultural land. On the other hand, coal-washing and the quarrying of china clay have largely increased, but in both of these cases it is of economic advantage that large quantities of suspended matter should not escape into the waste water.

38. We have satisfied ourselves that the general conditions in regard to existing forms of mining pollution are similar to those which were very fully investigated by the previous Commission, and we have therefore only called witnesses from those districts in which serious damage to important rivers is still taking place.

With regard to coal-washing waters, numerous analytical figures have been put before us by Dr. H. Maclean Wilson, Chief Inspector of the West Riding Rivers Board, and by Dr. J. T. Wilson, Medical Officer of Health to the Lanarkshire County Council.

In the cases of waste liquids from metalliferous mines and from china clay quarries, with regard to which no recent analytical figures were available, we caused special samples to be collected and analysed. The study of these analyses and the results of our own observations have satisfied us that the general findings of the previous Commission are still applicable.

39. We find with them that material injury may be caused to rivers, to agricultural land, to cattle and to fish through the discharge of liquid waste arising from the use of water in connection with mining operations. This injury is due to the

suspended matters which the liquids contain, and it may be prevented by the removal of such matters, which are capable of ready deposition in tanks or ponds.

As to the provision of tanks at every mine for the purpose of allowing six hours quiescent settlement of the waste water, whilst we agree that this would effect material improvement, we are inclined to think that the plan is not sufficiently elastic and that it would be liable to inflict unnecessary expense in a number of cases.

40. Some of the rivers in Cornwall which receive the unsettled waste waters from tin mines, or partially settled waste water from china clay works, are small, short streams of little importance; and, further, in the case of some of the small rivers which receive waste waters from tin mines, a certain number of persons are employed in the recovery of tin-stone from the suspended matter carried by the river water. In such cases we consider that the cost of the removal of suspended matters from the waste waters would be in excess of the benefit to the stream and the neighbourhood.

On the other hand, where the discharge is made into rivers which are important and valuable, for navigation or other purposes, it is clear that material injury may arise.

Coal-Washing.

41. As it is brought up from the pit, coal is found to be associated with shale and other matters such as iron pyrites, clay and stone. The proportion of shale or other matter in the coal is variable, being dependent upon the kind of coal worked, the thickness of the coal seam and other factors. Since the presence of shale or of iron pyrites or of non-combustible matter reduces the value of the coal, it is necessary that these impurities should be removed as far as possible.

The separation of the large pieces of such extraneous matter can be carried out effectively by hand. The "small" coal of 2 inches and less is riddled into various grades and then cleaned by agitation in running water. There are a number of special coal-washing plants available for this latter purpose. They are elaborate pieces of machinery and need not be described here. It will suffice to say that the process involves not merely washing in the ordinary sense, but the separation of the impurities from the coal by reason of their higher specific gravities.

The water, after use, is black and opaque, with much very fine coal, shale and dirt in suspension. It contains some dissolved matter over and above that originally present, but this consists mainly of soluble inorganic salts, and is usually small in amount. In a few instances where the coal contains much pyrites, however, some arsenic may be present in the wash water. (*Cf.* Fifth Report Rivers Pollution Commission, 1868, Vol. I., pp. 8 and 9.)

The discharge of this liquid into a stream is attended with several objectionable effects. The water of the stream is discoloured and rendered unfit for many secondary purposes, the bed of the stream is silted up, and its banks are blackened. If the discharge bears a large proportion to the volume of the stream, fish are destroyed and aquatic vegetation is detrimentally affected. If the stream overflows its banks, much black suspended matter may be deposited upon agricultural land.

The discharge of coal-washing water was a subject of inquiry by the Commission of 1868. They considered it a liquid liable to cause pollution of a very serious character (Fifth Report, Vol. I., p. 9), and recommended quiescent settlement as a fairly effective remedy (pp. 43 and 44).

Our own observation and the consideration of the evidence which has been given before us lead to the same general conclusions.

Since the publication of that Report settling tanks have been constructed at many collieries for the removal of small coal and other impurities from coal-washing water, and in a number of cases the clarified water is sent back to the washer for re-use. As showing the kind of result obtained, we may give some average figures which have been collated from a Report by Dr. H. Maclean Wilson to the West Riding Rivers Board, dated December 14th, 1900 :—

	Parts per 100,000.	
	Crude coal-washing water. Average of twenty-three analyses of chance samples drawn from twenty-three different plants.	Purified coal-washing water after settlement in tanks. Average of six analyses of chance samples drawn from five different plants.
Solids in solution :		
Volatile on ignition - - - - - -	29·25	40·3
Non-volatile - - - - - - -	329·25	290·4
Total - - - - - - -	358·50	330·7
Solids in suspension :		
Volatile on ignition - - - - - -	4383·8	about 0·8
Non-volatile - - - - - - -	1013·9	about 1·5
Total - - - - - - -	5397·7	2·6 (range 1·1—4·1)

The figures are not strictly comparable, but they serve to show how effective settlement may be in removing the matter in suspension. The effluents included in the above average are classed as good or fair by Dr. Wilson.

Other effluents classed as unsatisfactory contained from 4·8 to 10·0 parts of suspended matter per 100,000, while in a number of other cases the effluents contained much suspended matter and were classed as bad. At the time Dr. Wilson's Report was written there were forty-five sets of coal-washing plants in use in the West Riding. In twenty-one instances there was no direct discharge to the stream, the water being re-used.

Another set of figures, given in Wilson and Calvert's "Trade Waste Waters," page 21, may also be quoted here :

	Analyses of twelve samples of coal washing water after treatment.
Suspended solids - - - - -	2·8 (range 0·8 — 5·7)
Soluble solids - - - - - -	392·7 (range 178·0 — 950·0)

In Lanarkshire, in 1909, out of seventy-one collieries provided with coal-washing plant, sixty-seven were also provided with settling ponds and the effluent was re-used in sixty-four cases. (Second Report on the administration of the Rivers Pollution Prevention Acts by Dr. J. T. Wilson, 1909.)

In Durham and Lancashire similar measures are taken for removing suspended matter from the washing water, but in South Wales a good deal of fine coal still finds its way into the streams. The late Dr. W. Williams, Medical Officer of Health to the Glamorgan County Council, stated in evidence before the Commission (January 27th, 1909, Question 27979, *et seq.*) that only some twelve or eighteen colliery owners in his district had been induced to construct settling tanks or ponds.

The efficiency of settling tanks depends mainly upon their capacity in relation to the volume of liquid dealt with, and since coal-washing water contains a very large quantity of suspended matter, it follows that frequent cleansing of the tanks is necessary unless their capacity is very large in proportion to the flow. In this connection it may be useful to give the analytical figures relating to some average samples drawn at a colliery in South Wales. Large settling ponds are provided at this colliery, but at the time of sampling their capacity was much reduced by the solid matter which had settled in them. Incidentally the analyses show how slightly the water itself may be affected by coal-washing.

	No. 155.		No. 156.	
	Crude coal-washing water. Average of five samples, taken in equal quantities every hour from 7.30 a.m. to 11.30 a.m.		Partially settled coal-washing water. Average of five samples taken in equal quantities every hour from 7.30 a.m. to 11.30 a.m.	
	Drawn December 16th, 1909. Analysed January 19th, 1910.		Drawn December 16th, 1909. Analysed January 19th, 1910.	
	Original sample.	Paper-filtered sample.	Original sample.	Paper-filtered sample.
	Parts per 100,000.			
Ammoniacal nitrogen - -		0·038		0·038
Albuminoid nitrogen - -		0·022		0·007
Total organic nitrogen - -		0·032		?
Nitrous nitrogen - - -		0·0		0·0
Nitric nitrogen - - -		0·11		0·09
Total nitrogen, by Kjeldahl -	9·08	0·18	2·39	0·09
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) at once - - -		0·20		0·09
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) in 4 hours - -		0·50		0·54
Chlorine - - - - -		1·52		1·55
Hardness, by soap test, expressed as Carbonate of lime ($CaCO_3$) - - - - -		7·35		9·82
Solids in suspension - -	*1059·6 { 653·2 V.† 406·4 N.		204·8 { ‡80·0 V. 124·8 N.	
Solids in solution - - -		40·6 { 3·6 V. 37·0 N.		40·0 { 4·0 V 36·0 N.

* 68·4 of this came down in the Gooch filtrate on adding four drops of nitric acid and allowing to stand for about twenty-four hours. Of this, 13·6 was volatile.

† "V"=Volatile on ignition; "N"=non-volatile on ignition.

‡ 53·2 of this came down in the Gooch filtrate on adding three drops of nitric acid and allowing to stand about twenty-four hours. Of this 9·2 was volatile.

Notes on Samples when analysed :—

No. 155.—Black opaque liquid with no smell. Some of the solid matter was extraordinarily fine. The paper-filtered liquid (through Swedish paper) was fairly clear, with brownish opalescence. It deposited, however, an appreciable precipitate on standing.

No. 156.—Brown-black in appearance, with much extremely fine suspended solids. No smell. The paper filtrate (through Swedish paper) was nearly clear, with a faint dark opalescence. It deposited very little solid on keeping.

We may also refer to the evidence given on October 26th, 1909, by Mr. Percy C. Greaves and Mr. Roslyn Holiday, on behalf of the Mining Association of Great Britain.

As regards coal-washing water, Mr. Greaves said: "The effluent can be fairly easily dealt with, either by means of settling tanks or by passing the water through washed coal, and mixing the 'slimes' with the small coal for coking, and this is done at practically all the collieries I am connected with."

As regards (*a*) coal-washing water; (*b*) coke quenching water; and (*c*) water from blowing off boilers, Mr. Holiday said: "The solids in suspension in these effluents can be dealt with at a not excessive cost by means of settling tanks, or in the case of

(a) by passing the water through washed coal. In confined areas where the land is flat, the settling tank treatment is considerably higher in cost."

We have had no experience of the plan of filtering through small coal mentioned by these two witnesses.

It may be useful to add that at a colliery in Lanarkshire we saw a third method of disposal which appeared to be very effective. At this colliery the washing water is passed through settling tanks for the recovery of the larger particles of fine coal, and the partially clarified liquid is then pumped into large and deep excavations cut in a heap of waste shale. The water can only find its way out of these excavations by percolating through the shale, and it is thus filtered as well as settled before finding its way to the river. When one excavation becomes full of liquid it is left to drain and another is used.

At collieries where the fine coal is very dirty and where the washing plant is situated near a heap of fairly loose shale, the above plan would seem to be an admirable one. At the same time it should be noted that ferruginous drainings might issue from the heap after a little time if the shale contained much pyrites.

Summary as regards Coal Washing Water.

From the results obtained in the West Riding of Yorkshire and elsewhere, it is clearly evident that coal washing water can be effectively dealt with by settlement in tanks or ponds. In most cases some of the fine coal settled out of the washing water has a commercial value.

In the colliery districts of Yorkshire, Lancashire, Durham and Lanarkshire, the settled waters are frequently used over again, to the advantage of the coalowner.

Dr. Maclean Wilson's analytical figures and our own enquiries and observations lead us to believe that reduction of the suspended solids to 4 parts is quite practicable at a number of collieries.

At some collieries, where the coal is mixed with a good deal of clayey matter, there may be difficulty in reducing the suspended matter to such figures without the use of a coagulant.

Waste Waters from Tin Mines.

42. The chief ore of tin is tin-stone or dioxide of tin. It is a crystalline substance which varies in colour from grey, through yellow and brown, to black, according to the amount of oxide of iron which it contains. It occurs in veins or nodular masses, usually embedded in a rocky matrix, and often in association with the sulphides of arsenic, iron, copper, antimony and cadmium, as well as with oxide of iron.

The matrix containing the ore is roughly pulverized in a stream of water, and the turbid liquid which results is then allowed to trickle in thin streams over gently sloping "tables," for the purpose of separating the tin-stone from the siliceous and other matter with which it is mixed. The selective settlement is promoted by a sharp jerky motion which is given to the tables, the conditions of current velocity, etc., being so arranged that the heavier oxide of tin is deposited while the siliceous matter passes away with the water. This process has to be repeated (usually with variations) several times, and even then the separation is by no means complete.

The water carrying the siliceous matter in suspension is called the "tailing water." As a rule, it is discharged direct into the nearest stream, but when clear water is scarce, it is settled in tanks and then pumped back for re-use. The siliceous matter discharged in the tailing waters from a large tin mine amounts to many thousands of tons annually, and since the separation of the ore is incomplete, it is clear that not only oxide of tin, but all the other substances mentioned above are usually present also. Practically the whole of this matter is in suspension, however, though occasionally both arsenic and copper are present in solution in very appreciable quantities.

In their Fifth Report, Vol. I., p. 19, the Rivers Pollution Commission of 1868, after giving their analyses of various "tailing waters," make the following statement :—

> "The foregoing analytical results show that the effluent water from tin mines is polluting only by reason of matters in suspension. Amongst the numerous samples there is not one which even approaches the transgression of any of our proposed standards relating to dissolved matters; indeed, in most cases, mere subsidence leaves the supernatant water much purer than the average of potable waters supplied to towns, the only objectionable constituent in solution being arsenic, which is present, however, in but very small proportion. On the other hand, these waters grievously pollute and silt up the rivers into which they flow by the suspended matters contained in them. Each 1,000,000 gallons of water issuing from the Dolcoath mine, for instance, carried with it more than 80 tons of suspended rubbish, 200 lbs. of which are metallic arsenic, equivalent to 264 lbs. of white arsenic. Nearly the whole of this suspended matter is easily deposited when the water is quiescent. None of the samples contained copper in solution or exhibited any marked acidity."

Some samples of "tailing water" taken by us on March 15th, 1910, might be reported upon in very similar terms, except that one of them did contain a comparatively large quantity of copper in solution.

These samples gave the following figures on analysis :—

	Tailing water from Tin Mine No. 1.		Tailing water from Tin Mine No. 2.	
	Chance sample drawn on March 15th, 1910, 12 noon. Analysis begun March 17th.		Chance sample drawn on March 15th, 1910, 3.15 p.m. Analysis begun March 17th.	
	There were three bottles, the contents of which were mixed on March 17th and the suspended solids estimated. The liquid was then allowed to settle until March 21st, when it was siphoned into two bottles, which were kept full. There was a slight further settlement in these bottles.		There were three bottles, the contents of which were mixed on March 17th and the suspended solids estimated. The liquid was then allowed to settle until March 19th, when it was siphoned into two bottles, which were kept full. There was a slight further settlement in these bottles.	
Notes on sample when drawn.	Turbid, with bright red suspended matter in a fine state of division.		Turbid, with bright red suspended matter in a fine state of division.	
	Original sample.	Siphoned liquid.	Original sample.	Siphoned liquid.
	Parts per 100,000.			
Ammoniacal nitrogen* - -		0·007		0·002
Albuminoid nitrogen* - -		0·005		0·044
Nitric nitrogen* - - -		0·144		0·208
Oxygen absorbed from N/80 permanganate at 27° C. (80° F.) after 4 hours) -		0·034		0·145
Solids in suspension - -	1323·3 { 31·4 V. 1291·9 N.		2294·8 { 24·8 V. 2270·0 N.	
Solids in solution* - -	24·4 { 4·8 V. 19·6 N.		156·8 { 18·8 V. 138·0 N.	
Copper (as Cu) - - -		0·10 (colorimetrically)		3·28 (volumetric) 2·59 (gravimetric)
Tin, arsenic and antimony -		No ppt. with H_2S		No ppt. with H_2S
Oxide of iron and alumina (Fe_2O_3 and Al_2O_3) -		less than 0·20		3·72
Notes - - - -	The paper filtrate was slightly opalescent, and deposited 0·5 part of suspended solids in 24 hours (these are included above).		The filtrate was clear.	
	* The nitrogens were not estimated until April 29th ; the solids in solution, May 2nd.			
	Partial analysis of the Suspended Matter.			
Copper (as Cu) - - -	0·88 per cent.		0·87 per cent.	
Tin and antimony (as SnO_2 and Sb_2O_4) - - -	0·76 per cent.		0·82 per cent.	

These figures of analysis show that the liquid portion of both effluents was free, or practically free, from organic impurity. That from Mine No. 2, however, contained in solution about 3 parts of copper per 100,000. The solids in suspension were excessive, and these solids contained nearly 1 per cent. of copper and more than 0.5 per cent. of tin and antimony together.

Summary as regards Tailing Water from Tin Mines.

The tin mining industry in Great Britain is practically confined to Cornwall. Generally speaking, the mines are situated within a few miles of the sea, and the tailing waters are discharged into unimportant streams. The waters of these streams are rendered exceedingly turbid with suspended matter, the beds of the streams are silted up, and when floods occur agricultural land is damaged. We understand, however, that in the Camborne district, where the pollution is most conspicuous, no very serious complaints arise from the discharge of tailing water into streams. Here a considerable number of persons find employment in the separation of tin-stone from the suspended matter in the stream water.

Serious complaints as to injury to fish, and especially as to the destruction of spawning beds, do arise, however, with regard to the Tamar, Tavy and Camel, all three being valuable salmon rivers. Owing to the temporary shutting down of the tin mines in the Tavistock district, the injury to fish in the Rivers Tamar and Tavy is apparently not serious at present, but it is said to have been so at one time, and the mines are always liable to be reopened.

In cases such as these, reduction of the suspended matter is necessary. We have no data to show, as regards tin mines, what degree of settlement is reasonably attainable, but from the results obtained at other metalliferous mines it would appear that reduction to 6 parts per 100,000 might reasonably be asked for.

Waste Waters from Lead and Zinc Mines.

43. Galena, lead sulphide, is the most important of the lead ores. So far as this country is concerned, almost the whole of the lead of commerce is obtained from it. It often contains silver sulphide, and it occurs in association with the sulphides of zinc, copper, arsenic, antimony and iron. At one time lead was mined in a number of counties, but many mines have been shut down, and the industry is now confined mainly to North Wales, Cumberland, Lanarkshire and Derbyshire.

The galena is separated from the siliceous matrix, in which it is found embedded, much in the same way as tin-stone. The matrix is pulverized in running water and the galena and the zinc blende are separated by selective settlement from the turbid stream. The separation is usually imperfect, and the waste tailing waters carry with them appreciable quantities of galena, zinc blende, etc., in addition to much siliceous matter. These matters are practically all in suspension and, being of high specific gravity, are capable of ready settlement. Lead is present in solution only in traces, if at all; arsenic is frequently present, but in very small quantities. When the ore contains zinc carbonate, appreciable quantities of zinc may be discharged in solution.

The following analytical figures will show the character of the tailing waters produced at lead mines, and also the effects of good and of poor settlement upon them.

Lead Mine No. 3.

At this mine the tailing water is settled in two large ponds, used in series. The total capacity of the ponds at the time of sampling was about 3,750,000 gallons, and the total volume of tailing water discharged into them in 24 hours about 300,000 gallons. The bulk of the final effluent is pumped back for re-use.

	No. 198.		No. 199.	
	Unsettled tailing water. (Chance sample).		Final effluent as pumped back for re-use. (Chance sample).	
Drawn.	February 22nd, 1910, 11,30 a.m.		February 22nd, 1910, 12 noon.	
Analysis begun.	February 24th.		February 24th.	
	Original sample.	Paper-filtered sample.	Original sample.	Paper-filtered sample.
	Parts per 100,000.			
Ammoniacal nitrogen - -		0·003		0·002
Albuminoid nitrogen - -		0·005		0·005
Nitrous nitrogen - - -		0·0		0·0
Nitric nitrogen - - -		0·13		0·144
Total solids (dried at 105° C.)	1145·0 (by addition)		70·6 { 7·2 V. 63·4 N.	
Solids in suspension - -	1059·6 { 23·2 V. 1036·4 N.		1·4 { 0·7 V. 0·7 N.	
Solids in solution - -	85·4 { 8·0 V. 77·4 N.		69·2 (by difference)	
Lead (Pb) - - - -			0·016 (approximately)	
	There was no charring on igniting any of the above solids. The volatile matter, no doubt, consisted mainly of water of crystallisation and carbonic acid.			
Notes - - - -	As drawn, the sample was turbid and light brown, with much solid matter. It filtered through paper almost clear, though the filtrate could not be called sparkling.		This sample was faintly opalescent, and had a blue colour in bulk. It had no smell and did not froth. It filtered clear through paper.	
Examination of the water	The remaining liquid portion of both the above samples was siphoned from the bulk of the solids on March 22nd, and filtered from the small residues, still remaining, on April 18th, when it was further examined.			
Found—	Parts per 100,000.			
Lead (Pb) - - - -	0·015		0·025	
Zinc (Zn) - - - -	Probably 0·1 to 0·2		Probably about 0·1	
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$) - -	0·12		0·10	
Sulphate radical (SO_4) - -	43·99		35·97	
	Both the paper-filtered liquids were quite bright. The sulphate present was evidently calcium sulphate, for the most part.			
Examination of the solid matter.	Per cent. of dry solids.			
Found—				
Lead (Pb) - - - -	3·15			
Zinc (Zn) - - -	0·48			
	These solids also contained a trace of tin, but no other heavy metal. Iron, alumina and lime were, of course, present.			

While the crude water contained a large amount of solids in suspension (1059·6 parts), the effluent from the final pond contained only 1·4 parts.

The water itself had only traces of lead in solution. There was, however, a large quantity of lead (fully 3 per cent.) in the settled-out solids of No. 198.

The water was not rendered organically impure.

An additional sample of the final effluent from this mine was drawn on July 11th, 1913. It was practically free from solids in suspension. Tested for lead and zinc in solution, however it showed an appreciable quantity of the latter, thus :—

	Parts per 100,000.
Lead (Pb)	0·002
Zinc (Zn)	0·66

Lead Mine, No. 4.—At this mine settling ponds are provided for the tailing water. The final effluent is discharged into a small tributary of the River Severn.

	No. 200.		No. 201.	
	Unsettled tailing water. (Chance sample.)		Final effluent as discharged. (Chance sample.)	
Drawn.	February 24th, 1910.		February 24th, 1910, 11.40 a.m.	
Analysis begun.	April 22nd.		April 22nd.	
	Original sample.	Paper-filtered sample.	Original sample.	Paper-filtered sample.
	Parts per 100,000.			
Ammoniacal nitrogen		0·015		0·036
Albuminoid nitrogen		0·008		0·007
Nitrous nitrogen		0·0		0·0
Nitric nitrogen		0·040		0·064
Oxygen absorbed from N/80 permanganate at 27° C. in 4 hours		0·037		0·016
Total solids	393·4 (by addition)		69·8 (by addition)	
Solids in suspension	376·8 { 12·8 V. 364·0 N.		50·8 { 8·8 V. 42·0 N.	
Solids in solution	16·6 { 3·0 V. 13·6 N.		19·0 { 4·4 V. 14·6 N.	
	There was no charring on igniting any of the above solids.			
Lead (Pb)		0·04		0·06

Notes:—As drawn, this was a grey turbid liquid, containing much fine siliceous matter in suspension. No smell. No froth. After filtration through Swedish paper the liquid was very slightly opalescent in bulk. The Gooch filtrate was also very slightly opalescent.

Here, again, the liquid portion of both effluents was organically pure.

Analysis of the Solid Portion.—The clear liquid was siphoned from the solid portion on March 15th, 1910. The solid was then collected on filter paper and gently dried. It was then ground, dried at 105° C. and examined.

Found—	Per cent. of dry solids.
Silica	48·27
Lead (Pb)	3·55
Other heavy metals	None
Oxide of iron and alumina (Fe_2O_3; Al_2O_3)	25·20
Zinc (Zn)	Not tested for
Lime (CaO)	A little

As drawn, this was grey-coloured and rather turbid with suspended matter. No smell. No froth. The filtrate through Swedish paper was clear; the Gooch filtrate slightly opalescent.

An additional sample of the final effluent from this mine was drawn on July 10th, 1913. After a considerable quantity of suspended matter (21·8 parts) had been filtered off, the liquid portion gave :—

	Parts per 100,000.
Lead (Pb)	0·02
Zinc (Zn)	0·0

The suspended solids thus constituted the impurity in this effluent.

In the Fifth Report of the Rivers Pollution Commission of 1868, Vol. I., pp. 13 and 14, a large number of analyses of tailing waters from lead mines are given. Only traces of dissolved lead were found in any of these waters, and in summing up the results the Commissioners say (p. 15) :—

> "The above analytical results demonstrate that the pollution of rivers by lead mining arises altogether from matters in suspension; indeed, as regards polluting matters in solution, the water used on the dressing floors of these mines is frequently discharged in a condition of greater purity than it possessed before use. The suspended polluting matter consists chiefly of mineral mud; the comparatively small proportion of organic matter which it contains is probably derived in great part from the soluble organic constituents contained in the water used for the washing operations."

On the same page the Commission say as regards four small streams near Aberystwyth :—

> "All these streams are turbid, whitened by the waste of the lead mines in their course; and flood waters in the case of all of them bring down poisonous 'slimes' which, spreading over the adjoining flats, either befoul or destroy the grass, and thus either injure cattle and horses grazing on the dirtied herbage, or, by killing the plants whose roots have held the land together, render the shores more liable to abrasion and destruction on the next occasion of high water. It is owing to the latter cause as well as to the immense quantity of broken rock which every mine sends forth that the small rivers Rheidol and Ystwyth present such surprising widths of bare and stony bed. . . . The evidence taken before us at Aberystwyth and Machynlleth is conclusive as to the great loss thus occasionally inflicted on the generally small farmers who occupy these riverside lands. . . . We are bound to add that, excepting the destruction of ducks and other poultry reported to us at mines near Hexham on the north side of the River Tyne, where large quantities of carbonate of baryta are obtained (to deposits of which in the roadways and river channels, no doubt this fatality is due), no complaints from stock owners in the neighbourhood of lead mines in the north of England have been made to us. The valleys are wider and there is ample space for storage of waste materials around these mines in Allendale, Teesdale and Weardale; and the moorland which may be occasionally overflowed by the muddy waters is of comparatively little value.
>
> In Derbyshire, on the other hand, the mines are on a smaller scale, and these waste waters are a comparatively insignificant addition to the streams into which they flow."

Damage of the kind referred to is still reported occasionally on the banks of several small streams in North Wales. It is said to occur after a flood, and to consist mainly in damage to cattle and to fish. The cases are not frequent.

Summary as regards Lead and Zinc Mines.

Pollution by tailing water from lead and zinc mines is confined to a few rivers at the present time.

Damage arises mainly from the discharge of suspended matter which silts up the bed of the stream, and in time of flood may be washed on to the adjoining meadows.

That it is possible to reduce the suspended matters in such tailing waters by settlement is shown by the analysis given on p. 15. We have, however, few data on the settlement of such tailing waters, and this result may be somewhat exceptional. We cannot, therefore, with confidence, suggest any definite figure to which it would be generally practicable to reduce the suspended solids, but we think that if they were brought down to 6 parts per 100,000 there would be little danger of poisoning by lead or arsenic.

Special provision might have to be made in the case of tailing waters containing zinc in solution.

Wastes from China Clay Pits.

44. China clay, or kaolin, is a hydrated silicate of alumina. It is formed in nature as the result of the action of water and carbonic acid upon minerals like feldspar, a silicate of potassium and aluminium. Potassium carbonate is formed, and this dissolves away, leaving the silicate of aluminium as a white crumbly mass, mixed with quartz and mica.

A stream of water is allowed to flow down the side of the pit in such a way as to carry the soft clay, together with the quartz, etc., to the bottom of the pit. After short settlement to remove the larger crystals of quartz and other extraneous matters, the creamy white mixture is pumped up to the surface and settled in tanks. The deposited clay is subsequently removed from these tanks and dried over ovens. As a rule, some of the tank effluent is pumped back for re-use, but there is always a considerable quantity running to waste. This waste water still contains much china clay in suspension, and for this reason it is milky white in appearance.

Most of the streams draining the china clay districts are white with china clay in suspension, and a milky appearance is also imparted to the sea water at the mouths of some of these streams. In several estuaries there are large banks of quartz and china clay, derived from the clay pits.

As showing that the impurity in the waste water from china clay pits consists entirely of matter in suspension, we may give the figures of analysis relating to the single effluent as discharged from four large pits in the St. Austell district of Cornwall.

Sample No. 204.—Clay pit-water as discharged from four clay pits.

Drawn.—Thursday, March 19th, 1910.

Note on Sample when drawn.—Milky liquid, but without smell on shaking.

Analysed.—April 29th, 1910.

	Parts per 100,000.
Ammoniacal nitrogen - - - - - - -	0·005
Albuminoid nitrogen - - - - - - -	0·009
Nitric nitrogen - - - - - - - -	0·132
Oxygen absorbed from N/80 permanganate at 27° C. (80 F.) after 4 hours - - - - - - -	0·086
Total solids - - - - - - - - -	58·8 { 10·4 V. 48·4 N. (No charring on ignition.)
Solids in suspension - - - - - - -	47·0 { 6·4 V. 40·6 N. plus 1·6 { 1·4 V. 0·2 N. (A small portion of the suspended solids came through the first Gooch asbestos. The second Gooch filtrate was quite clear.)
Notes - - - - - - - - - .	Milky liquid, with very fine white solids. No smell. This waste liquor was free from heavy metals and also from the metals of the iron group.

These figures are in agreement with those given by the Commission of 1868 (Fifth Report, Vol. I., p. 29), and they show that the impurity is entirely in suspension, the water itself being organically pure. After giving a number of analytical figures relative to china clay works, that Commission reported as follows:

> "The analytical results embodied in the above table show that the spring which rises in the chief clay pit near St. Austell furnishes one of the purest waters on record. It is absolutely free from organic matter, and 100,000 parts of it contain only 5·6 parts of foreign substances, the chief constituent of which is common salt. This water after use is polluted only by suspended matters, and these, after complete subsidence in settling pits, leave the water even purer than before its use for clay-washing, as is seen from a comparison of the results yielded by the first and third samples in the above table. The brook used for china clay-washing at the Vale Pleasant Works, near St. Austell, is of excellent quality. It issues from the mica pits charged with all the clay in suspension, but after complete subsidence the original purity of the water is not impaired. The same remarks also apply to the water used at the Gazelan Works. Unfortunately, however, the effluent water from clay works is rarely allowed to subside completely. Thus the white stream from the Gazelan Works still retained, in 100,000 parts, 251·6 parts of suspended matter, which is, however, innocuous to animal life."

A few laboratory experiments made by that Commission (Fifth Report, Vol. 1, p. 42) may also be quoted:—

> "XVI. Of 100 parts of suspended matter contained in the white waste water flowing from a clay pit at St. Austell, 11·56 parts were deposited in the first quarter of an hour and 47·68 parts in the next six hours, leaving 40·76 parts still in suspension. Here again the turbid water had been submitted in various clay pits to prolonged subsidence and the sample operated upon contained only 47·44 parts of suspended matter in 100,000 parts of water."
>
> "XVII. A much less favourable result was obtained in the experimental subsidence of the muddy water discharged from the Gazelan clay works. Although this waste discharge contained as much as 251·6 parts of suspended clay in 100,000 parts of water, it deposited only 2·8 per cent. in the first quarter of an hour and 32·3 per cent. in the next six hours, leaving no less than 64·89 per cent. still in suspension."

Summary as regards China Clay.

China clay occurs in various parts of Cornwall and also in Devonshire, but by far the largest quantity is found and worked in the St. Austell district. No serious complaints as to injury to rivers and streams in this district have been made to us at the present time. It is clear, however, that china clay, though itself innocuous to human life and to cattle, might in some rivers cause extensive injury, either through the destruction of fish, and especially of spawning beds, or through the silting up of the river or its estuary.

In such cases settlement would be necessary, but we have no data to show what degree of clarification would be practicable.

Stone Quarrying.

45. At some of the granite and whinstone quarries the smaller grade stone is crushed and washed before it is riddled. The washing is usually effected by spraying water on to the stone as it travels down a sloping trough to the riddles. The result is a wash-water containing much finely divided mineral matter in suspension.

The following figures of analysis will give a general idea as to the nature of these wash-waters from quarries; they refer: (1) to the wash-waters from a granite quarry before and after partial settlement; and (2) to the unsettled wash-waters from a whinstone quarry.

(1) *Washings from No. 5 granite quarry, in Warwickshire.* The volume of water used per 24 hours was estimated to be about 3,000 gallons. It was pumped from the quarry. At the time of the inspection the wash-water was passing through a small pit (about 20 feet by 12 feet by 3 feet), excavated in the ground. After leaving this pit it flowed along a small grip to another pit about half the size of the first, and from this it passed into a canal. Both pits were almost full of deposited grit, so that little settlement of suspended matter could be expected. Two samples were drawn and examined.

Number of sample	320 K.	321 K.
Nature of sample	Wash-water from granite washings.	Wash-water after passing through pond.
Drawn	March 29th, 1912.	
Analysed	April 2nd, 1912.	
Parts per 100,000		
Ammoniacal nitrogen	0·012	0·008
Albuminoid nitrogen	0·013	0·017
Nitrous nitrogen	0·00	0·00
Nitric nitrogen	0·58	0·50
Oxygen absorbed from N/80 permanganate at 27° C. (80° F.) in 4 hours	0·068	0·071
Chlorine	2·04	2·12
Solids in suspension	7,366 { 198 V. 7,168 N.	3,967 { 142 V. 3,825 N.
Remarks	Cloudy liquor after settlement overnight. Slow-settling. Very fine reddish-brown deposit.	Slightly turbid liquor after settlement. Very large quantity of fine red silt. No smell.
Note on Rate of Settlement.		
April 1st—		
Total height of mixed liquid and solids at 10.30 a.m.	14·8 c.m.	16·2 c.m.
Total height of settled solids:—		
at 1.15 p.m.	8·5 c.m.	7·8 c.m.
at 5.0 p.m.	5·9 c.m.	5·6 c.m.
April 2nd—		
Total height of settled solids at 10.0 a.m.	4·0 c.m.	3·6 c.m.

The water of these effluents, while it could not be called organically pure, was fairly so, *i.e.*, the impurity of the effluents consisted practically in their suspended solids, which settled out but slowly.

(2) *Washings from whinstone quarry No.* 6, *in the North Riding of Yorkshire.* Only a small quantity of water is used for washing. After falling from the riddles it is passed into a very small sump to remove the larger particles of stone, and then into the turbine race which flows into the Tees.

Nature of sample	A.—Undiluted waste water from No 6 Quarry, as running to turbine sluice. Volume over 50,000 gallons a day.	B.—Turbine and mill-wheel water after receiving the wash-water from No. 6 Quarry, as flowing to the river Tees.
Drawn	March 21st, 1912.	
Analysed	March 22nd, 1912.	
Parts per 100,000.		
Ammoniacal nitrogen	0·004	0·004
Albuminoid nitrogen	0·015	0·011
Nitrous nitrogen	0·00	0·00
Nitric nitrogen	0·051	0·048
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.) at once	1·07	0·34
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.) in 4 hours	1·72	0·51
Chlorine	0·66	0·83
*Hardness (as $CaCO_3$)	10·5	7·3
Hardness (after boiling)	—	6·9
Total solids	$324{\cdot}0\begin{cases}14{\cdot}4\text{ V.}\\309{\cdot}6\text{ N.}\end{cases}$	$31{\cdot}2\begin{cases}9{\cdot}2\text{ V.}\\22{\cdot}0\text{ N.}\end{cases}$
Solids in suspension	$234{\cdot}1\begin{cases}4{\cdot}6\text{ V.}\\229{\cdot}5\text{ N.}\end{cases}$	$17{\cdot}9\begin{cases}1{\cdot}4\text{ V.}\\16{\cdot}5\text{ N.}\end{cases}$
Oxygen in solution	—	1·11
Dissolved oxygen taken up from water at 18° C. (65° F.) in 5 days	0·34	0·05

In this case the crude wash-water contained a large quantity of suspended matter, but little dissolved impurity.

Adequate settlement in ponds would practically restore the water to its original condition of purity. The bulk of the solids in these wash-waters is rapidly deposited, but usually some very finely-divided particles of siliceous matter remain in suspension, even after long settlement.

The following experiments made with another sample of the wash-water from this quarry will illustrate this latter point :—

Settling Experiments.

Nature of Sample.—Wash-water from Quarry No. 6 (six half-Winchester bottles drawn).

Drawn.—2.30 p.m., September 3rd, 1912.

Experiment begun October 28th, 1912.

The contents of two of the bottles were transferred to a Winchester quart. This mixed sample contained :—

$$\text{Suspended solids—}336{\cdot}4\begin{cases}11{\cdot}8\text{ V.}\\324{\cdot}6\text{ N.}\end{cases}$$

The Winchester was then almost emptied into a wide glass tube, closed by a stopper at the lower end. The tube was 3 feet 10 inches (115·8 c.m.) long, by 2 inches (5·3 c.m.) internal diameter. The wash-water was allowed to settle in this for 6 hours, when samples were drawn off at depths of 2 feet and 3 feet from the surface, respectively.

October 29th—

$$(a)\ \text{2 feet sample—Suspended solids—}41{\cdot}6\begin{cases}1{\cdot}5\text{ V.}\\40{\cdot}1\text{ N.}\end{cases}$$

$$(b)\ \text{3 feet sample—Suspended solids—}52{\cdot}1\begin{cases}2{\cdot}0\text{ V.}\\50{\cdot}1\text{ N.}\end{cases}$$

Both of the Gooch filtrates from these suspended solids were quite cloudy, but the solids were not visible as discrete particles. The drawing of these two samples had brought the liquid down to the one foot mark ; it was done quietly, so as not to disturb the mixture in the tube. After 25 hours' settlement, a third sample was drawn at the 3 feet mark.

October 30th—

$$(c)\ \text{Suspended solids—}18{\cdot}7\begin{cases}1{\cdot}2\text{ V.}\\17{\cdot}5\text{ N.}\end{cases}$$

This precipitate (from the 25 hours' settlement) was too fine to be all retained by the asbestos in the Gooch crucible ; the filtrate was still cloudy.

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* All the figures for hardness given in this report mean "Hardness as determined by soap test."

October 31st—

The filtrates from (*a*), (*b*) and (*c*) were combined and filtered through a fresh Gooch crucible :—

Suspended solids, $2{\cdot}1\begin{cases}0{\cdot}2\text{ V.}\\1{\cdot}9\text{ N.}\end{cases}$

The filtrate was still faintly cloudy.

November 1st—

The filtrate was now acidified with three drops of nitric acid and allowed to stand until the 4th.

November 4th—

Suspended solids, $2{\cdot}6\begin{cases}0{\cdot}1\text{ V.}\\2{\cdot}5\text{ N.}\end{cases}$

Even now, the filtrate was still slightly cloudy.

November 14th—

This last filtrate was again filtered :—

Suspended solids, $0{\cdot}7\begin{cases}0{\cdot}2\text{ V.}\\0{\cdot}5\text{ N.}\end{cases}$

This filtrate was at last clear and almost bright.

Summary of foregoing Experiments :—

Six hours' settlement to a depth of 2 feet left in the siphoned portion fully 40 parts suspended solids.

Six hours' settlement to a depth of 3 feet left fully 50 parts suspended solids.

Twenty-five hours' settlement to a depth of 2 feet left about 20 parts suspended solids.

After standing for three weeks in the tube, there was a top layer of 6 inches which was nearly clear. The liquid at the foot of the tube (above the deposited solids) then contained probably something like 0·5 part suspended solids per 100,000.

Stone Polishing.

46. At one time, when stone flags were extensively used in kitchens and sculleries, the stone polishing industry was a considerable one, but it has diminished greatly during the last twenty years, and at the present time only a few polishing plants are at work.

In 1912 we visited one quarry, No. 6A, where stone polishing was still carried out. The bulk of the stone from this quarry was being prepared for kerbs and building, but a small portion was polished in addition to being sawn and planed. A small quantity of water is allowed to run on to the stone as it is sawn, planed and polished. It carries with it much fine gritty matter, but is not materially affected as regards soluble impurities.

The total flow of waste water from this quarry is about 40,000 gallons per working day, and the total tank capacity 230,000 gallons.

The following analytical figures were obtained from samples drawn on the occasion of this visit, when the settling tanks were comparatively clear of solids :—

Nature of sample - - -	397.—Chance sample of crude wash-water from polishing, sawing and planing.	398.—Effluent from settling tanks. Chance sample of water as leaving ponds and flowing to river.
Drawn - - - -	June 20th, 1912.	
Analysed - - - -	August 22nd, 1912.	
Parts per 100,000		
Ammoniacal nitrogen - - - - -	0·002	0·002
Albuminoid nitrogen - - - - -	0·002	0·002
Nitrous nitrogen - - - - - -	0·00	0·00
Nitric nitrogen - - - - - - -	0·240	0·208
Oxygen absorbed from N/80 permanganate in 4 hours at 27° C. (80° F.) - - - -	0·018	0·018
Solids in suspension - - - - - -	$76{\cdot}8\begin{cases}3{\cdot}8\text{ V.}\\73{\cdot}0\text{ N.}\end{cases}$	$6{\cdot}0\begin{cases}0{\cdot}4\text{ V.}\\5{\cdot}6\text{ N.}\end{cases}$
Remarks - - - - - - - -	Turbid, with fine greyish solids.	Turbid, with very fine greyish-brown suspended matter.

Good settlement was thus obtained and the water, after use, was pure, organically.

Sample No. 397, settled in the laboratory for 7 hours, and drawn off at a depth of 9 c.m. from a bottle 13 c.m. deep, gave 7·0 parts of suspended solids.

Summary as regards Stone Quarrying and Stone Polishing.

Since only small quantities of water are required in stone quarrying and stone polishing and sawing, good settlement is not a difficult matter. From the few data which have just been given as regards stone polishing, together with further data relating to stone sawing obtained by Messrs. Wilson and Calvert (Trade Waste Waters, p. 228), we think that the suspended solids might be reduced without undue trouble or expense to 6 parts per 100,000.

SECTION II.

LIQUID WASTES WHICH ARE POLLUTING MAINLY BECAUSE OF THE SUSPENDED MATTER WHICH THEY CARRY WITH THEM, BUT ALSO TO A CONSIDERABLE EXTENT BECAUSE OF THE DISSOLVED IMPURITIES WHICH THEY CONTAIN.

47. Under this head may be classed the majority of liquid trade wastes. It includes the waste liquors from dyeing, printing and bleaching (except kier liquor) in the cotton trade, from yarn, piece, flannel and blanket scouring and from dyeing (except with indigo) in the woollen and worsted trades, from paper mills where wood pulp constitutes the raw material, and from other trades of lesser importance. In all these trades water is used as a solvent as well as a mechanical carrier.

48. Soluble salts of a poisonous nature, such as sodium arsenate, lead acetate, "pink salt" (a double chloride of tin and ammonium), and potassium bichromate, are frequently used in some branches of the cotton and woollen trades, but their harmful constituents are largely precipitated or abstracted from solution in the trade process, and, for this reason, only small traces are usually to be found in the waste liquors. When the purification of the waste liquors from such trade processes includes chemical precipitation, the quantity is still further diminished.

We are inclined to think that chemical precipitation might well be adopted at most works where soluble poisonous substances are used in the trade processes.

49. The mineral substances dissolved in these trade liquors, though not usually poisonous, may very seriously impair the quality of the water with which the liquors are mixed. They may be acids, alkalies, or substances which cause water containing them to be hard; they may corrode metals; they may throw down objectionable deposits on the river bed; or they may be injurious to fish life. In some cases, as, for instance, in woollen piece and yarn scouring, and in cotton printing, the waste liquors are soapy, while in others they are strongly coloured with dyes.

50. We know of no practicable means by which liquids containing these dissolved impurities can be rendered perfectly innocuous, but since conditions of excessive acidity, alkalinity or hardness frequently arise from carelessness on the part of the manufacturer, and such conditions may render the river water unfit for subsequent use by manufacturers, it may be necessary to set up limits in respect of acidity, alkalinity and hardness.

The matter in suspension or colloidal solution in this class of liquid trade waste consists largely of wool, cotton or wood fibre, with grease (usually in the form of an emulsion), gummy matter, starch, etc. It is objectionable in rivers for many reasons; it fouls the river bed, silts up mill dams, making them liable to produce nuisance from smell in hot weather, causes objectionable scum or excessive frothing, and is injurious to fish life. If present in any considerable quantity it renders the water unfit for many manufacturing purposes.

We are satisfied from the evidence which has been given before us by manufacturers that it is, in the majority of cases, practicable to remove much of the suspended and colloidal matter from these liquid trade wastes. In many cases simple sedimentation suffices for this purpose, while in others chemical precipitation followed by settlement gives good results.

51. At a number of mills it has been found practicable to provide filters as well as settling tanks. These filters are usually so small in proportion to the volume of liquid dealt with as to preclude the possibility of any considerable purifying action except that of mechanical straining. When kept clean, however, they are useful in this latter respect, especially in those cases where the suspended matter carried in the waste liquor is of low specific gravity, or, for any other reason, difficult to settle out.

52. As regards the colour of liquid trade wastes, we may say that while it is possible to remove this by the use of bleaching agents, the cost of the process would, in many cases, be in excess of the benefit to the river. It is desirable, however, that the

colour should be removed as far as practicable, and since chemical precipitation is to a considerable extent effectual in this respect with most coloured liquids, we are inclined to think that it should constitute a part of the process of purification of all strongly coloured trade wastes. In cases where, for special reasons, it is essential that the effluent should be colourless, recourse must be had to bleaching agents or to filtration through land or through pressure coagulant filters.

The Cotton Industry.

(1) *Dyeing.*

53. The process of cotton dyeing is seldom carried out as a separate business. It is almost always associated with the antecedent process of bleaching, and also in many cases with printing. The processes of bleaching and dyeing are distinct from one another, and they are sometimes carried out in separate buildings, but the waste liquors are usually collected by means of an intercepting drain, and so become more or less intermixed before being discharged for purification.

As the contents of various vats are sent into the drains indiscriminately, the general waste liquor is subject to great and continuous variation in composition. Very often it consists almost wholly of the discharge from a single vat. Moreover, the proportion of waste bleach liquor to waste dye liquor varies greatly at different works.

As a general rule, the establishments at which cotton dyeing is carried out are situated in districts more or less rural in character, one reason for this being that a plentiful supply of clean water is required, mainly for the process of bleaching, but also for that of dyeing.

Some dyes, as, for instance, congo red, are withdrawn from solution by the goods which are being dyed, and impart to the latter a depth of colour depending upon the strength of the solution and the affinity of the material for the dye. In such cases the cloth is simply immersed in a solution, usually hot, of the dye, and then washed free from excess of dye with clean water. The dyed cloth is usually run through a "starch solution" and then dried.

Other dyes, and these comprise the majority, are not directly taken up by the fabric in this way. The latter has therefore to be impregnated with a substance capable of attaching itself first to the fabric and subsequently to the dye. Substances of this kind are called mordants. They are usually salts of weak bases or acids, such as the acetates of aluminium and chromium, double chloride of tin and ammonium, and certain salts of iron. Some of the mordants commonly used are of a poisonous nature.

As the coloured compounds of the dye and the mordant are more or less insoluble, soap solutions are often used to remove the excess of colour from the fabric.

Waste Liquor from Direct Dyeing.—With the direct dyes the waste liquor is composed of the nearly exhausted dye solution and the water used to remove the excess of dye. It varies continually in composition, but may be described in general as a coloured liquid containing a certain amount of fibre and starch in suspension, together with a considerable quantity of matter, mainly inorganic, in solution. Although rather highly coloured, it contains only very small quantities of the dye in solution.

Waste Liquor produced when a Mordant is used.—Where the dye is used in conjunction with a mordant the waste liquor is often soapy, and it carries much matter in suspension, including the insoluble compound of the mordant and the dye. The liquid itself is not, as a rule, highly coloured, but it may contain a good deal of matter, mainly inorganic, in solution, and also traces of any poisonous substances which are being used as mordants.

As showing the kind of crude waste liquors which are produced at dye works and the effluents obtained from these by means of settling tanks and straining filters, we may give some figures relating to two dye works situated in the Mersey and Irwell watershed and one in the Ribble watershed. In each case the tank capacity is large in proportion to the daily flow.

Dye Works, No. 7.

All the waste liquors from these works are treated together. They include dye liquor, bleach liquor, waste liquor from mercerising, and general wash waters. The total volume is about 1,000,000 gallons per working day. The liquors from the dye, bleach and mercerising processes are mixed together and treated with lime and alumino-ferric at the entrance to the first settling tank, but the kier liquor from the bleaching is first collected in a special tank and then allowed to flow equably into the first settling tank.

From the first tank the mixed liquors are pumped into and allowed to settle in a series of eight tanks, the last three of which are used on the quiescent settlement plan and drawn off alternately. The total tank capacity is 819,000 gallons. The sludge from the tanks is pressed and carted away. The tank liquor is finally streamed through shallow clinker filters which have a superficial area of 120 square yards.

Three chance samples of this final effluent gave the following analyses :—

	No. 1.		No. 2.		No. 3.	
Sample drawn	January 9th, 1911, 11.30 p.m.		January 7th, 1911, 10.30 a.m.		January 7th, 1914, 3.0 p.m.	
Sample analysed	January 10th, 1911.		January 11th, 1911. (In ice, 10th–11th.)		January 9th.	
Parts per 100,000.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.
Ammoniacal nitrogen	0·05	0·05	0·06	0·06	·07	
Albuminoid nitrogen	0·16	0·15	0·19	0·12	·09	
Total organic nitrogen	0·45		0·86		·11	
Nitrous nitrogen	0·0				0·0	
Nitric nitrogen	0·25		0·15		0·36	
Total nitrogen (by Kjeldahl)	0·75		1·07		0·54	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) at once					0·49	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) in 4 hours	9·72	8·40	7·93	7·11	4·26	3·55
Incubator test (by smell)	Putrid ; sulphides.		Passed.		Passed.	
Dissolved oxygen taken up from water at 18° C. :—						
In 24 hours			0·01	0·03		
In 48 hours	2·65 + x†		1·54	0·43		
In 3 days	2·65 + x	1·91			3·90	
In 5 days			3·85 + x	3·10	5·90	4·58
Solids in suspension	5·8 {3·5 V. 2·3 N. The Gooch filtrate was bright and clear.		3·6 {2·6 V. 1·0 N. Filtrate clear and bright.		3·7 {1·7 V. 2·0 N.	
Total hardness, expressed as carbonate of lime, $CaCO_3$	20·1		22·0		26·6	
Permanent hardness, expressed as carbonate of lime, $CaCO_3$	14·8		16·7		20·0	
Alkalinity, expressed as sulphuric acid, H_2SO_4					15·5 (Methyl Orange). 7·9 (Phenol-phthaleïn).	
Alkalinity, expressed as sulphuric acid, H_2SO_4, after boiling					10·5 (Phenol-phthaleïn).	
Notes	The sample was brownish and opalescent, with a small amount of fine suspended matter and a spent bleach odour. A considerable precipitate of carbonate of lime adhered to the glass of each bottle, which could not be removed.		The sample was yellowish and opalescent, with some very fine suspended matter. It had a spent bleach odour and contained a trace of hypochlorite. Alkaline. Here, again, there was a considerable deposit of carbonate of lime in each bottle.		Brownish and opalescent, with very little suspended matter. Slight odour of spent bleach.	

† "+x" means that all the oxygen in the mixture has been used up.

The three foregoing samples were very similar, both in appearance and composition, though sample No. 1 failed to withstand incubation. They were, especially Samples No. 2 and 3, comparatively free from suspended solids, the liquid portion of the effluent being clear and bright. The figures for the permanganate test were high, and those for dissolved oxygen absorption moderate. No. 1 took up little oxygen in the first twenty-four hours, but after that the absorption was rather rapid. Neither the hardness nor the alkalinity was excessive.

Two chance samples of sludge were examined:—

Number of Sample.	No. 1.		No. 2.
Drawn	July 11th, 1913.		Friday, Jan. 16th, 1914. In ice, Jan. 17th.
Analysis begun	July 14th.		Jan. 20th.
	Parts per cent.		Parts per cent.
Moisture	62·34		64·0
Dry matter	37·66		36·0
	100·00		100·0
Residue left on ignition	27·85		27·0
	Calculated on :		This sample was found to contain 2·03 per cent. of fatty acids.
	Wet Sludge.	Dry Matter.	
Nitrogen (N_2)	0·16	0·43	
Phosphoric acid (P_2O_5)	0·11	0·29	
Silica and silicates	4·88		
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$)	3·70		
Lime (CaO)	3·05		
Magnesia (MgO)	5·33		
Copper (Cu)	0·028		
Arsenic (As)	0·027		
Lead, antimony, tin, zinc	Absent.		

Dye Works No. 8.

At this dye works some average samples of the crude liquor and the final effluent were drawn in April, 1913, and a chance sample of effluent in November. The total volume of waste liquor amounts to about 250,000 gallons per working day of 10½ hours. First, milk of lime and then alumino-ferric are added to the waste liquor and the mixture is passed first through settling tanks and then through a small filter before being discharged to the river. The settling tanks are three in number, and have a total capacity of approximately 325,000 gallons. They are cleaned out every five weeks. The sludge is drained on sludge filters and tipped when sufficiently dry to be carted. There are three sludge filters. They are composed of coarse ashes (3 feet 6 inches deep) covered with a (6 inch) layer of fine ashes, and they have a total area of 938 square yards.

Average figures of analysis of 4 sets of average samples drawn on April 1st, 2nd, 3rd, and 4th, 1913. These samples were made up of equal samples taken every hour from 8·30 a.m. to 5·30 p.m.

Parts per 100,000.

Analysed April 3rd, 4th, 7th and 8th.

	Crude waste liquor.		Precipitation liquor as leaving settling tanks.		Final effluent as discharged to stream.		Final effluent; chance sample drawn Nov. 26th, 1913, analysed Nov, 28th.
Ammoniacal nitrogen	†(0·01—0·08)	0·03	(0·01—0·02)	0·01	(0·01—0·02)	0·02	0.01
Albuminoid nitrogen	(0·28—0·37)	0·32	(0·16—0·23)	0·19	(0·17—0·21)	0·19	0.05
Total organic nitrogen	(0·82—0·99)	0·94	(0·39—0·58)	0·49	(0·42—0·66)	0·49	—
Nitrous nitrogen -			Sample too coloured to test.				0.0
Nitric nitrogen - -	(0·10—0·33)	0·21	2 samples contained 0·06 each 2 samples were putrid and contained H_2S		2 samples contained 0·06 each 2 samples were putrid and contained H_2S		— 0.08
Total nitrogen (by Kjeldahl) - -	(0·98—1·26)	1·14	(0·46—0·59)	0·53	(0·45—0·73)	0·54	0.10
Oxygen absorbed from N/8 permanganate at 27° C. *at once* - - -	(3·17—4·11)	3·48	(0·49—0·95)	0·73	(0·64—0·99)	0·77	0.33
Oxygen absorbed from N8 permanganate at 27° C. *in four hours* - - -	(13·37—16·54)	14·94	(4·31—7·11)	6·16	(4·32—6·20)	5·41	1.44
Incubator test (by smell) - - -	—		—		4 failed out of 4		—
Total solids - -	(178·8—217·6)	191·7 {33·2 V.* 158·5 N.	(70·0—88·2)	79·5 {20·7 V. 58·8 N.	(75·2—87·8)	79·6 {16·8 V. 62·8 N.	—
Solids in suspension -	(8·2—11·3)	9·9 {8·7 V. 1·2 N.	(4·0—5·3)	4·7 {2·5 V. 2·2 N.	(2·9—6·3)	5·0 {2·9 V. 2·1 N.	1.9 {1.0 V. 0.9 N.
Solids in solution -	(169·8—206·6)	181·8	(65·0—83·8)	74·8	(68·9—83·5)	74·6	—
Alkalinity (expressed as H_2SO_4) - -	(5·23—8·20)	6·42	(2·04—6·11)	3·57	(3·40—5·23)	4·05	2.37
Total hardness (as $CaCO_3$) - - -	(4·57—5·43)	4·79	(5·86—8·57)	6·86	(5·57—8·14)	6·82	
Permanent hardness (as $CaCO_3$) - -	(4·57—5·71)	5·21	(4·57—6·57)	5·75	(4·57—7·57)	5·89	
Chlorine (present as chloride) - -	(13·46—17·80)	15·76	(7·10—10·00)	9·12	(7·58—10·07)	9·33	
Dissolved oxygen taken up from tap-water at 18° C. in 48 hours - -	(3·20—5·00)	4·28	(3·36—4·63)	4·13‡	(3·72—4·44)	3·99‡	1.35‖
Dissolved oxygen taken up from tap-water at 18° C. in 5 days - - -	(7·58—9·74)	8·59	(5·40—10·50)	8·75	(5·58—8·37)	7·10	1.84

‖ 3 Days. * V = Volatile. N. = Non-volatile. † Figures in brackets indicate minimum and maximum figures. ‡ Average of 3 samples.

It will be seen from these figures that although the impurities in the crude liquor are mainly inorganic, yet organic impurities are also present, and these have the power of taking up oxygen at a considerable rate. The tank treatment reduces the suspended matter from 9·9 to 4·7 parts per 100,000, but has no effect on the oxygen absorbing power of the liquor. The small filter produces practically no effect either as regards clarification or oxidation. From the marked difference in the chlorine figures of these average samples of crude waste and precipitation liquor, it would appear that a considerable quantity of clean water gains access to the settling tanks.

The figures of the chance sample of effluent, when compared with those of the average samples, show how the effluent from a works of this kind may vary in composition at different times of the day.

In order to test whether the absorption of dissolved oxygen by the final effluent was due to the solids in suspension or to the matter in solution, sample A 3 (containing 6·3 parts of suspended solids per 100,000) was filtered through Swedish filter-paper on April 30th, and the absorption of dissolved oxygen from tap-water in 5 days was estimated:

Original sample - - - - - - 7·90 parts of oxygen per 100,000
Paper-filtered sample - - - - - 6·50 „ „ „

It is thus evident that the absorption was mainly due to the matter in solution.

A chance sample of sludge was drawn from a heap on the ground in April, 1913; this had been run out of the tanks about the end of December, 1912.

Number of sample	A 4	
Drawn	April 4th, 1913 (in ice, April 6th).	
Analysis begun	June 12th, 1914.	
	Parts per cent.	
Moisture	77·9	
Dry matter	22·1	
	100·0	
Residue left on ignition	11·8	
	Calculated on :	
	Wet sludge.	Dry matter.
Nitrogen (N_2)	0·62	2·81
Phosphoric acid (P_2O_5)	0·076	0·34
Silica and silicates (*i.e.*, matter insoluble in acid, ignited)	7·18	
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$)	1·34	
Lime (CaO)	0·24	
Magnesia (MgO)	0·39	
Lead (Pb)	0·014	
Copper (Cu)	0·004	
Arsenic (As)	0·006	
Antimony, tin and zinc	Absent.	

When analysed, this sludge was black, thick and greasy, but not putrid.

It has a small manurial value, in virtue of the nitrogen which it contains.

Dye Works No. 9.

From tables handed in by Mr. Edward Halliwell, who gave evidence before us on January 27th, 1909, the following figures relating to a dye works in the Ribble Watershed have been obtained.

At this works the processes of dyeing and bleaching are carried on together. In the main aniline colours are used. The whole of the waste liquors from the works, amounting to about 200,000 gallons per working day of 12 hours, are given continuous flow settlement in tanks which have a total capacity of 270,000 gallons.

WORKS No. 9.

	Parts per 100,000.	
	Crude dye liquor. Average of four chance samples.	Dye tank effluent. Average of four chance samples.
Unfiltered sample.		
Ammoniacal nitrogen	0·41	0·16
Albuminoid nitrogen	0·27	0·28
Oxygen absorbed from N/80 permanganate in 3 minutes	3·37	1·98
Oxygen absorbed from N/80 permanganate in 3 minutes (after incubation)	3·57	2·15
Oxygen absorbed from N/80 permanganate in 4 hours	8·84	7·77
Suspended solids	33·5 { 22·7 V. 10·8 N.	12·7 { 5·1 V. 7·6 N.
Dissolved solids	182·0 { 41·2 V. 140·8 N.	137·5 { 42·75 V. 94·75 N.
Filtered sample.		
Ammoniacal nitrogen		0·14
Oxygen absorbed from N/80 permanganate in 3 minutes	2·31	1·38
Oxygen absorbed from N/80 permanganate in 4 hours	6·69	7·64

As showing the kind of effluent which may be discharged from a works where the processes of dyeing, printing and bleaching are all carried on together, we may give our analytical figures for the final effluent from a Turkey red dye works No. 10.

At this works the waste liquids are collected by means of a system of intercepting drains and small receiving tanks, and then mixed and allowed to settle in four tanks, used in series. The total capacity of these four tanks is approximately 200,000 gallons, and the total volume of waste liquor dealt with about 1½ million gallons per working day. As the work is carried on only in the day time, the flow of waste liquor is at the rate of about 3 million gallons per 24 hours and the average stay in the tanks about 1·6 hours.

FINAL EFFLUENT FROM TURKEY RED DYE WORKS NO. 10 AS LEAVING SETTLING TANKS.

Kind of sample	Average of 24 hours, drawn in equal quantities ever hour.
Appearance of sample	Reddish-brown liquid containing reddish brown suspended matter. Very little smell. Slight tendency to froth.
Sample drawn	February 1st to 2nd, 1910.
Sample analysed	February 12th, 1910.
	Parts per 100,000.
Ammoniacal nitrogen	0·03
Albuminoid nitrogen	0·22
Total organic nitrogen	0·46
Nitrous and nitric nitrogen	0·08
Total nitrogen (by Kjeldahl method)	0·57
Oxygen absorbed from N/8 permanganate at 27° C. at once	2·38
Oxygen absorbed from N/8 permanganate at 27° C. after 4 hours	12·93
Incubator test as judged by smell	Passed (strong, musty smell).
Total hardness (as $CaCO_3$)	7·7
Permanent hardness (*i.e.*, after boiling)	6·6
Alkalinity (as H_2SO_4) (Methyl orange)	7·8
Dissolved oxygen taken up from tap water at 18° C. in 48 hours	10·7
Total solids	57·6 { 30·3 V. 27·3 N.
Solids in suspension	7·5 { 4·6 V. 2·9 N.

A sample of the crude waste liquor from the same works, drawn as it entered the tanks, was tested for mineral constituents, with the following results :—

	Parts per 100,000.
Heavy metals (lead, etc.)	None, excepting possible traces of the tin group.
Oxide of zinc	None.
Oxide of chromium (Cr_2O_3)	0·06
Oxide of iron and alumina (with possible traces of silica)	1·16
Lime (containing probably a little magnesia)	2·98

Summary as regards Dyeing.

The analytical figures which have been given show that dye works, as usually carried on, produce waste liquids which are polluting, not only on account of the suspended matter which they carry with them, but also by reason of the dissolved impurities which they contain. At the same time, it is clear that liquids such as these cannot be considered foul in the same sense as domestic sewage. The impurities which they contain both in suspension and solution are largely inorganic, and the organic matter is not for the most part of a kind liable to undergo offensive decomposition.

We are inclined to think that, in most cases, the main objection to the discharge of such liquids into streams not used for domestic or manufacturing purposes is on account of the matter which they carry in suspension. They would, doubtless, be injurious to fish life, especially if they contained much free acid or alkali.

From the figures relating to the final effluents from the various works cited, and from our general observation, it is clear that settlement in tanks, with or without the preliminary addition of chemicals, does materially reduce the suspended matter contained in these dye waters, but that a good deal still remains in the effluents even although the tank capacity provided may be equal to something like a day's flow.

The analyses show that much dissolved matter still remains in the effluents. The addition of precipitants appears to have some effect upon the soluble impurities in the liquors, but the use of certain chemicals may tend to increase the "hardness" of the liquids.

As regards the presence of free alkali in mixed bleach and dye liquors, it must be borne in mind that settlement in tanks has no effect on this, and that even when chemicals, other than acids or acid salts, are used, the neutralising effect can be only very slight.

All the witnesses called before us agreed that the suspended impurities in dye and bleach liquors could be removed to a large extent by the use of settling tanks, but it will be seen that there was some difference of opinion as to whether this treatment could be said to produce a satisfactory effluent.

Mr. Edward Halliwell, Chief Inspector to the Ribble Joint Committee, in his evidence before us on January 27th, 1909, said that :—

> "Treatment in tanks with or without the addition of precipitants removes a large amount of suspended matter in the form of sludge. The effluents still contain suspended matter. In some cases, they are highly coloured, in some they are distinctly putrefactive, and in others give rise to slimy growths in the beds of streams."

Mr. R. A. Tatton, late Chief Inspector, Mersey and Irwell Joint Committee, said, as regards print and dye works, that "we must look to chemical precipitation, with or without subsequent filtration through artificial filters, as the process to be adopted." Appendix, No. 1, First Report Vol. III.

Mr. W. Naylor, late Chief Inspector, Ribble Joint Committee, classes liquid dye waste as of a very objectionable character, but suggests that chemical precipitation followed by settlement gives good results. Appendix, No. 2, First Report Vol. III.

Mr. Hugh Stowell and Mr. Frank Scudder, officers of the Mersey and Irwell Joint Committee, in their evidence on March 26th, 1909, stated that out of 101 dye works in their district, 79 had provided purification plant, usually tanks, capable of producing satisfactory results.

On further enquiry for figures of analysis, Mr. Stowell (in a letter dated 27th April, 1911) gave the following results relating to cotton dyeing :

No. of satisfactory samples.	Average solids in suspension, in parts per 100,000.	No. of samples where suspended solids were nil.
204	4·1	66

On a general review of all these data, we think it reasonable to suggest that a dye-works effluent ought not to contain more than 4 parts of suspended solids per 100,000. At the same time it should be remembered that a cotton dye-works effluent, even after such clarification, is capable of taking up a considerable amount of oxygen from water.

(2) *Printing.*

54. In the process of printing, as distinguished from dyeing, the colour or mordant to be imparted to the fabric by means of engraved rollers is first made into a thick paste with some glutinous substance such as starch. The print roller revolving in this paste becomes completely covered with it, but before coming into contact with the fabric, the excess of paste is removed by a scraper fitted to the roller in such a way as to leave the paste in the engravings only.

The printing of cotton may be carried out in a number of ways, the chief of which are as follows :—

(1) The colour is printed direct on to the fabric.

(2) The fabric is immersed in a mordanting solution and then printed with a dye.

(3) The fabric is printed with a mordant and then immersed in a solution of a dye.

(4) The fabric is printed with a mordant and then with a dye.

(5) The fabric is dyed and printed with a bleaching paste.

A number of colours may be printed on the same fabric, and in elaborate printing the fabric may be subjected to all the above processes. In addition to the organic dye-stuffs, mineral dyes like chromate of lead are used to some extent, while the mordants include salts of aluminium, chromium and tin, sodium arseniate, sodium sulphate, ammonium phosphate, etc. The thickening substances used for the actual printing include various gums, starch, sugar, glue, china clay, etc.

The use of water arises in the washing of the fabric to remove either excess of dye or mordant, and also in the cleaning of the rollers after use. A certain amount of water is used in mixing the colours and mordants, and where the cloth is mordanted or dyed in vats, there is the usual spent dye liquor and wash water from the vats. The fabric to be washed is usually passed through a hot solution of potash soap. This gradually becomes more and more charged with colour and thickening until it is no longer fit for use. In some works the residual soapy liquor is treated for the recovery of the fatty acids, but this is exceptional and the solution is usually discharged as waste.

The print rollers are scraped after use and then scrubbed with soap and water. This produces a thick and highly coloured waste liquor.

At large print works, as much as 500,000 or even 1,000,000 gallons of waste water per day are commonly discharged, but this includes the waste liquors from the bleaching and dyeing processes, which are usually carried out in conjunction with the printing.

Mainly on account of the necessity for a plentiful supply of clean water, print works are usually situated in rural districts.

The mixed waste liquor from a print works may be described in general terms as a soapy liquid containing much highly coloured matter in suspension, and much glutinous matter both in suspension and in colloidal solution. It may contain small quantities of poisonous mineral matters, but these are mainly in suspension. A considerable quantity of dissolved matter, mainly inorganic, is always present in the waste liquors from a print works.

With the object of showing the kind of waste liquors which are produced at print works, and the effect of settlement (in some cases with filtration) upon them, we may give some figures of chemical analysis relating to such works :—

Calico Print Works No. 11.

The processes of bleaching, printing, and, to some extent, dyeing, are carried on at this works. The whole of the waste liquors gravitate to a sump where they become mixed. The mixture is pumped from this sump to the settling tanks. The total volume of mixed waste liquor is about 200,000 gallons per working day of twelve hours. The settling tanks are three in number, and they have a total capacity of 536,000 gallons. When the crude waste liquor is very highly coloured, blocks of alumino-ferric are placed in the channel leading to the settling tanks. The sludge from the settling tanks is tipped.

The waste liquor is given on the average about twelve hours' quiescent settlement, after which the supernatant liquor is run on to filters, four in number, which have a total superficial area of 1,333 square yards. The depth of the filtering material is 3 feet. These filters are used in pairs, the settled liquor being streamed, first by upward flow through one filter, and then by downward flow through another.

Average figures of analysis of 4 sets of average samples drawn on April 8th, 9th, 10th, and 11th, 1913. These samples were made up of equal samples taken every half hour from 6·0 a.m. to 6·0 p.m.

Parts per 100,000.

Analysed April 10th, 11th and 14th.

	Crude waste liquor.			Precipitation liquor as leaving settling tanks.			Final effluent as discharged to stream.		
Ammoniacal nitrogen - -	*(0·02—0·06)	0·05		(0·02—0·10)	0·04		(0·02—0·07)	0·04	
Albuminoid nitrogen - -	(0·15—0·43)	0·23		(0·17—0·22)	0·19		(0·18—0·23)	0·20	
Total organic nitrogen -	(0·31—1·09)	0·60		(0·36—0·53)	0·46		(0·38—0·54)	0·44	
Nitrous nitrogen - - -				Sample too coloured to test.					
Nitric nitrogen - - -	(0·23—0·29)	0·26		(0·09—0·21)	0·15		(0·06—0·13)	0·10	
Total nitrogen (by Kjeldahl)	(0·59—1·39)	0·90		(0·59—0·68)	0·63		(0·51—0·69)	0·56	
Oxygen absorbed from N/8 permanganate at 27° C. "at once" - - -	(2·84— 5·02)	4·18		(1·98—2·71)	2·36		(1·85— 2·61)	2·23	
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours - - -	(13·87—24·68)	19·82		(12·42—13·61)	12·98		(11·60—12·57)	12·10	
Incubator test (by smell) -	——			—			1 passed, 3 failed.		
Total solids - - -	(81·2—113·6)	91·7	52·7 V.† 39·0 N.	(70·4—79·2)	74·0	36·5 V. 37·5 N.	(69·2—74·4)	71·8	39·3 V. 32·5 N.
Solids in suspension - -	(13·8—38·4)	22·0	16·8 V. 5·2 N.	(4·5—12·4)	7·2	5·9 V. 1·3 N.	(4·2—6·8)	5·7	4·9 V. 0·8 N.
Solids in solution- - -	(59·6—75·8)	69·7		(58·0—73·9)	66·8		(62·8—72·2)	66·6	
Alkalinity (expressed as H_2SO_4) - - - -	(5·43—19·01)	12·90		(10·18—13·60)	12·06		(10·86—12·22)	11·77	
Total hardness (as $CaCO_3$) -	(10·30—13·76)	11·62		(12·11—14·52)	12·94		(11·20—13·76)	12·97	
Permanent hardness (,, ,,)	(3·90—9·43)	7·91		(10·00—12·56)	11·05		(9·71—11·65)	10·83	
Chlorine (present as chloride)	(3·82—9·22)	6·62		(3·73—5·79)	5·02		(3·73—6·00)	5·24	
Dissolved oxygen taken up from tap water at 18° C. in 48 hours - - -	(2·92—6·86)	5·26		(1·60—3·22)	2·31		(3·57—6·59)	4·74	
Dissolved oxygen taken up from tap-water at 18° C. in 5 days - - -	(7·71—21·60)	14·93		(5·50—9·72)	8·12		(11·62—15·57§)	13·19	

* Figures in brackets indicate minimum and maximum figures. † V. = Volatile. N. = Non-volatile. ‡ Average of 3 samples.
§ Five-sixths of 6 days.

Four chance samples of the final effluent from the same works gave the following figures of analysis :—

	Final effluent, as discharged.							
	No. 1.		No. 2.		No. 3.		No. 4.	
Sample drawn	January 14th, 1911.		January 21st, 1911.		December 2nd, 1913, 10.30 a.m.		December 15th, 1913.	
Sample analysed	January 17th.		January 27th. (Delayed in transit.)		December 4th.		December 17th.	
	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.
Parts per 100,000.								
Ammoniacal nitrogen	0·03	0·02	0·03	0·03	·01		0·06	
Albuminoid nitrogen	0·17	0·11	0·19	0·10	0·02		0·39	
Total organic nitrogen	0·45		0·51		0·53		0·69	
Nitrous nitrogen	Too coloured.		0·0					
Nitric nitrogen	0·11		0 0		0·02		0·13	
Total nitrogen (by Kjeldahl)	0·59		0·54		0·56		0·88	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) at once					3·05		4·18	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) in 4 hours	8·71	7·07	10·20	5·85	16·82		14·96	
Incubator test (by smell)	Passed. (Strong spent bleach odour.)		Failed. (Putrid ; sulphides.)		Putrid ; H_2S.		Putrid ; H_2S.	
Dissolved oxygen taken up from water at 18° C. in 24 hours			4·45	2·05				
Dissolved oxygen taken up from water at 18° C. in 48 hours	4·13	2·24			7·6		12·4	
Dissolved oxygen taken up from water at 18° C. in 5 days	7·55*	5·53*	14·4	8·80	27·1	21·6	34·7 + x	19·7
Solids in suspension	$7{\cdot}8\left\{\begin{array}{l}5{\cdot}3\text{ V.}\\2{\cdot}5\text{ N.}\end{array}\right.$ The Gooch filtration went very slowly. The filtrate was bluish-pink in colour, opalescent and soapy. It deposited only a very slight precipitate on keeping for ten days.		$7{\cdot}8\left\{\begin{array}{l}6{\cdot}2\text{ V.}\\1{\cdot}6\text{ N.}\end{array}\right.$ Gooch filtrate opalescent. By February 22nd, it had deposited further solids, viz. : $6{\cdot}4\left\{\begin{array}{l}5{\cdot}0\text{ V.}\\1{\cdot}4\text{ N.}\end{array}\right.$ The filtrate was now only very slightly opalescent.		$13{\cdot}3\left\{\begin{array}{l}11{\cdot}3\text{ V.}\\2{\cdot}0\text{ N.}\end{array}\right.$		$7{\cdot}4\left\{\begin{array}{l}6{\cdot}8\text{ V.}\\0{\cdot}6\text{N.}\end{array}\right.$	
Total hardness (as $CaCO_3$)	34·0		27·4				17·4	
Permanent hardness (,, ,,)	27·2		27·0				15·3	
Alkalinity (expressed as H_2SO_4)					17·7 (Methyl Orange)†		16·3 (Methyl Orange.)†	
Notes	Three bottles of this sample were received, each with some air at the top. They were not mixed. The sample was reddish-brown and turbid, with some dark-coloured suspended matter. Soapy smell. Considerable froth on shaking. The paper-filtered sample was still opalescent, but much lighter in colour.		There were again three bottles of this sample. They were not mixed. The sample was pinkish-brown and turbid, with considerable suspended solids. Soapy and earthy smell. The paper filtrate was clear. February 21st : A little froth on shaking bottle, which had stood partly full.		This sample had a slight purple colour and a soapy smell.		Purple coloured and with a soapy smell.	

* 4 Days. † Acid to Phenol-phthaleïn in the cold.

The crude liquor from this works is dilute, and the impurities which it contains are mainly inorganic, yet a very considerable amount of oxygen is taken up from water in 48 hours and 5 days. The tank treatment reduces the suspended matter from 22·0 parts per 100,000 in the crude liquor to 7·2 parts, but the filters only effect a very slight further reduction. The tank treatment in this case does appear materially to diminish the dissolved oxygen absorption by the crude liquor, though this may be partly due to leakage of subsoil water into the tanks (*cf.* chlorine figures), because it is clear from the following experiment that the oxygen absorption is due mainly to the dissolved impurity in the liquor.

Part of effluent sample No. B3 (containing 4·2 parts of suspended matter per 100,000) was filtered through Swedish filter paper on April 30th, the dissolved oxygen absorption in 5 days by the unfiltered and paper-filtered portions being then estimated. The original sample was found to take up 7·9 parts of oxygen per 100,000 and the paper-filtered portion 6·5 parts.

The last two chance samples of effluent examined—Nos. 3 and 4—were of distinctly poorer quality than the average samples.

In order to gain some idea of how far effluents like the foregoing were amenable to further purification by precipitation, a few laboratory experiments were made with the chance sample of effluent, No. 3. The best results were obtained by using 5 parts alumino-ferric and 24 parts of lime per 100,000 of effluent. This yielded a perfectly clear, though slightly yellowish, liquor, of greatly better quality than the original effluent, or than the effluent minus its "filterable" solids, as the following figures show:—

	"Oxygen absorbed" from N/8 permanganate at 80° F. in 4 hours.
Original effluent, No. 3 - - - - - -	16·9
Gooch filtrate from this effluent - - -	13·0
Precipitation liquor, filtered through paper -	4·3

Good results could no doubt be obtained in practical working by the use of smaller quantities of precipitants. More attention might, we think, be given at some works to obtaining the best practicable precipitation results.

It may be added that bubbling air through the original effluent for 5 hours brought about no precipitation of the colloidal matter present.

A chance sample of sludge was taken from the higher part of the lagoon where the sludge is air-dried and drained.

Number of sample - - - - -	B. 4.	
Drawn - - - - - - -	April 10th, 1913.	
Analysis begun - - - - - -	June 12th.	
	Parts per cent.	
Moisture - - - - - - -	64·9	
Dry matter - - - - - - -	35·1	
	100·0	
Residue left on ignition - - - -	16·1	
	Calculated on:	
	Wet sludge.	Dry matter
Nitrogen (N_2) - - - - - -	0·46	1·31
Phosphoric acid (P_2O) - - - - - -	0·12	0·34
Silica and silicates - - - - -	10·35	
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$) -	7·27	
Lime (CaO) - - - - - - -	0·73	
Magnesia (MgO) - - - - - -	2·20	
Lead (Pb) - - - - - - -	0·094	
Copper (Cu) - - - - - - -	0·006	
Arsenic (As) - - - - - -	0·21	
Antimony, tin, zinc - - - - -	Absent.	

This sludge was putrid and mouldy at the date of analysis. It has some manurial value, because of the nitrogen which it contains. Its calorific value must also be considerable.

Calico Print Works No. 12.

Samples were drawn at two purification plants attached to two large print works, Nos. 12 and 12A, in the Ribble Watershed.

Plant A.—The main purification plant receives the waste liquors from two works belonging to the Company. The trade in the first case is calico printing and dyeing, the chief dye used being Turkey red; in the second case it consists mainly in yarn dyeing. The total volume of liquid waste sent from the two works for purification is about 1,500,000 gallons per working day. The purification works consist of two rectangular tanks, each of 750,000 gallons capacity. They are used separately for quiescent settlement, the period of quiescence varying from 2 to 6 hours, according to the flow of the trade waste.

The tank liquor, usually very well clarified, is run direct to a small brook. No precipitants are used at the purification works, but copperas is added from time to time at the dye house when the dye becks are being run off. About 50 tons of copperas are used per annum. A very large volume of sludge is produced as the result of the tank treatment. As no use can be found for it, it is tipped in a small ravine close to the tanks. The accumulation now amounts to many hundreds of thousands of tons.

Average figures of analysis of 4 sets of samples drawn on May 27th, 28th, 29th and 30th, 1913. The samples of crude waste are average ones, being made up of samples drawn every half hour from 6.30 a.m.—4.0 p.m. The samples of tank liquor consist of a mixture of two samples, one being drawn at 9.0 p.m. and the other at 6.0 a.m.

Analysed May 29th and 30th; June 2nd and 4th.

Parts per 100,000.

	Crude Waste.		Tank Liquor as discharged to Brook.		Crude Waste, Chance Sample, Drawn Dec. 2nd, 1913. Analysed, Dec. 4th.
Ammoniacal nitrogen - -	(0·02—0·14)	0·07	(0·03—0·06)	0·05	
Albuminoid nitrogen - -	(0·10—0·28)	0·20	(0·08—0·15)	0·13	
Total organic nitrogen - -	(0·46—0·72)	0·55	(0·33—0·54)	0·47	
Nitrous nitrogen - - -	—	—	—	—	
Nitric nitrogen - - -	(0·30—1·04)	0·58	(0·29—0·39)	0·33	
Total nitrogen (by Kjeldahl) -	(0·97—1·70)	1·19	(0·67—0·99)	0·85	0·98
Oxygen absorbed from N/8 permanganate at 27° C. "*at once*" - - - -	(3·83—5·09)	4·34	(0·42—2·81)	1·73	2·23
Oxygen absorbed from N/8 permanganate at 27° C *in* 4 *hours* - - - -	(8·71—21·20)	14·73	(4·67—7·99)	6·36	12·29
Total solids - - - -	(159·6—306·4)	225·7 { 81·1 V. 144·6 N.	(125·6—140·4)	133·3 { 40·4 V. 92·9 N.	
Solids in suspension- - -	(37·2—130·0)	82·8 { 24·7 V. 58·1 N.	(4·4—6·8)	5·6 { 2·8 V. 2·8 N.	23·1 { 11·7 V. 11·4 N.
Solids in solution - - -	(120·8—176·4)	142·9	(120·1—136·0)	127·5	
Total alkalinity, as H_2SO_4 (by Methyl Orange) - - -	(13·6—about 80)	about 47	(12·2—17·2)	15·6	
Caustic alkalinity, as H_2SO_4 (by Phenol-phthaleïn) - -	(0·0— 45·1)	12·4	(0·0— 2·0)	0·5	
Total hardness, as $CaCO_3$ -	(53·8—115·9)	75·8	(47·2—67·3)	57·2	
Hardness after boiling ,, -	(41·5—109·3)	61·2	(35·7—58·3)	47·1	
Incubator test (by smell)- -		—		4 passed out of 4	
Dissolved oxygen taken up from tap-water at 18° C. *in* 5 *days* - - - -	(8·8—23·3)	16·1	(6·44—8·46)	7·28	11·3

It will be seen that in this case the crude waste not only contains a large quantity of suspended matter, but that it gives a high figure for "permanent hardness." The impurities are mainly inorganic, but the organic matter which is present has the power of taking up oxygen at a considerable rate. The tank treatment is very effective, reducing the suspended matter from 82·8 to 5·6 parts per 100,000, on the average, but the tank liquor still takes up a considerable quantity of dissolved oxygen in 5 days

The following figures relate to some chance samples of the tank liquor from this works :

	Tank Liquor, as discharged.					
	No. 1.		No. 2.		No. 3.	
Sample drawn	January 18th, 1911, 2 p.m.		Friday, January 20th, 1911, 3 p.m.		Tuesday, December 2nd, 1913, 10.30 a.m.	
Sample analysed	January 19th.		January 23rd.		December 4th.	
	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.
Parts per 100,000.						
Ammoniacal nitrogen	0·50	0·50	0·44	0·44	0·05	
Albuminoid nitrogen	0·21	0.16	0·16	0.16	0·11	
Total organic nitrogen	0·74		0·39		0·16	
Nitrous nitrogen	0·0		Too coloured.		Too coloured.	
Nitric nitrogen	0·42		0·70		0·88	
Total nitrogen (by Kjeldahl)	1·66		1·43		1·11	
"Oxygen absorbed" from N/8 permanganate at 27° C. at once	—	—	—	—	0·0 (?)	
"Oxygen absorbed" from N/8 permanganate at 27° C. in 4 hours	4·62	4·05	8.20	6.97	5·11	
Incubator test (by smell)	Passed.		Passed. (This was incubated : *(a)* alone ; *(b)* with addition of a few drops of a putrid sewage effluent.)		Passed (musty smell).	
Dissolved oxygen taken up from water at 18° C. in 24 hours	0·55	0·99	0·15	0·12		
Dissolved oxygen taken up from water at 18° C. in 48 hours	0·55	1·40	0·32	0·40	0·42	
Dissolved oxygen taken up from water at 18° C. in 5 days	9·10	7·70	0·95	0·45	7·14	5·10
Solids in suspension	$4\cdot8\left\{\begin{array}{l}2\cdot2\text{ V.}\\2\cdot6\text{ N.}\end{array}\right.$		$5\cdot7\left\{\begin{array}{l}2\cdot4\text{ V.}\\3\cdot3\text{ N.}\end{array}\right.$		$5\cdot6\left\{\begin{array}{l}2\cdot0\text{ V.}\\3\cdot6\text{ N.}\end{array}\right.$	
	The Gooch filtrate was strongly yellow, but clear and bright. It only deposited a mere trace of precipitate in a week.		The Gooch filtrate was yellow and somewhat opalescent. It deposited a slight orange precipitate in two weeks. This amounted on February 10th to :— $3\cdot0\left\{\begin{array}{l}1\cdot6\text{ V.}\\1\cdot4\text{ N.}\end{array}\right.$			
Total hardness (as CaCO$_3$)	60·8		59·7		75·0	
Permanent hardness ,, ,,	56·8		56·2		77·4	
Alkalinity, as H_2SO_4 (Me.O.)	—	—	—	—	17·7	
Caustic alkalinity, as H_2SO_4 (Phenol-phthaleïn)	—	—	—	—	5·4	
"Free" chlorine (tested by iodide)	A good deal.		0·61			—
"Available" chlorine (tested by iodide and acid)	Much.		9·10			—
Notes	The sample was brownish-yellow and opalescent, with some fine brown suspended matter. The smell was like that of linoleum. After paper filtration, the liquid was clear and bright yellow. Reaction alkaline.		Brownish yellow and opalescent from some fine reddish solid. Strong spent bleach odour. Alkaline. The paper filtrate was bright yellow, but clear.		This sample was bright yellow and fairly clear. It smelt of nitro-benzene. The suspended solids were reddish.	

The most polluting of the liquors which go to make up the total waste from these two works is the soda kier liquor. As showing the composition of this we may give the following figures of analysis :

Chance sample of *Kier liquor* from *First Caustic Soda boil*, drawn Thursday, May 29th, 1913, at 1.0 a.m.
Analysed June 14th, 1913.

	Parts per 100,000.
Ammoniacal nitrogen	0·82
Total organic nitrogen	17·41
Total nitrogen (by Kjeldahl)	18·23
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	274·1
Total solids	1971·2 { 1046·4 V. 924·8 N.
Total alkalinity (by Methyl Orange) as H_2SO_4	781·0
Caustic alkalinity (by Phenol-phthaleïn) as H_2SO_4	308·1
Starch*	50·0 approx.
Dissolved oxygen taken up from tap-water at 18° C. *in 48 hours*	97·0
Dissolved oxygen taken up from tap-water at 18° C. *in 5 days*	119·0

* Estimated by comparing the blue colour given with iodine against that given by a standard solution of potato starch.

It will be seen that the liquor (which was dark brown, with very little suspended matter) was strongly alkaline, both with caustic and carbonated alkali, and that it took up a very large quantity of dissolved oxygen in 5 days.

A chance sample of the sludge from this works was also examined. It was taken from a lagoon and was a portion of the sludge last run from the tanks two days previously.

Number of sample	A.13.	
Drawn	May 28th, 1913. (Put in ice on June 2nd)	
Analysis begun	June 8th.	
	Parts per cent.	
Moisture	81·2	
Dry matter	18·8	
	100·0	
Residue left on ignition	12·3	
	Calculated on :	
	Wet Sludge.	Dry Matter.
Nitrogen (N_2)	0·07	0·37
Phosphoric acid (P_2O_5)	0·46	2·45
Sulphuric acid (SO_3)	0·16	—
Carbonic acid (CO_2)	Much.	—
Silica and silicates (*i.e.*, matter insoluble in acid, ignited)	0·68	—
Oxides of iron, aluminium and chromium (Fe_2O_3, Al_2O_3, Cr_2O_3)*	4·60	—
Lime (CaO), precipitated once	3·59	18·6
Magnesia (MgO)	0·30	—
Lead (Pb)	0·86	4·57
Copper (Cu)	0·022	—
Arsenic (As)	0·20	1·06
Tin (Sn)	Trace.	—
Antimony	Absent.	—

* Whether any of the chromium present was in the form of chromate was not tested.

This sample was quite fresh when it came to be analysed.

It is difficult to see to what use such a sludge—as a whole—could be put. Experiments might be made on it with a view to the partial separation and utilisation of some of its constituents.

Plant B.—The waste liquor dealt with on this plant is derived from a works where the processes of calico printing and crimping are carried on. The latter process yields a large volume of liquor which contains free caustic alkali and dextrine. The mixed waste is usually strongly coloured.

The purification plant consists of four rectangular tanks having a total combined capacity of about 350,000 gallons. They are used for continuous flow settlement in two series of two tanks each. No precipitant is added at the tanks, but alumino-ferric is occasionally mixed with the strong dye water at the dye house. The tank liquor is finally strained through filters before being discharged into a small brook.

There are two small filters. They are filled with clinker of 1 inch to 2 inches in diameter, and fed by means of fixed distribution pipes. Their combined capacity is about 130 cubic yards.

The sludge from the tanks is run into lagoons.

Average figures of analysis of 4 sets of average samples drawn on May 27th, 28th, 29th and 30th, 1913. Samples were taken every half hour from 7.0 a.m. to 4.0 p.m
Analysed May 29th and 30th; June 2nd and 3rd.

Parts per 100,000.

	Crude waste.		Tank liquor.		Effluent as discharged to brook.		Chance Samples.	
							Tank liquor.	Filter effluent.
							Drawn Tues., Nov. 11th, 1913, 11.30 a.m. Analysed Nov 13th.	
Ammoniacal nitrogen	(0·01—0·05)	0·03	(0·01—0·06)	0·03	(0·02—0·13)	0·05	0·02	0·01
Albuminoid nitrogen	(0·12—0·20)	0·15	(0·19—0·24)	0·21	(0·19—0·29)	0·23	0·20	0·19
Total organic nitrogen	(0·18—0·55)	0·32	(0·37—0·51)	0·45	(0·32—0·56)	0·43	0·51	0·41
Nitrous nitrogen	——		——		——		0·20	0·10
Nitric nitrogen	(0·17—0·34)	0·23	(0·00—0·27)	0·12	(0·00—0·11)	0·06	0·05	0·14
Total nitrogen (by Kjeldahl)	(0·45—0·76)	0·57	(0·55—0·71)	0·61	(0·44—0·58)	0·52	0·79	0·66
Oxygen absorbed from N/8 permanganate at 27° C. *at once*	(1·52—3·76)	2·97	(1·85—5·57)	3·77	(1·77—6·27)	3·83	2·00	1·64
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	(6·58—14·63)	11·31	(10·43—15·22)	12·65	(9·94—14·24)	11·86	13·45	12·12
Total solids	(79·2—113·2)	95·4 { 37·9 V. 57·5 N.	(86·8—101·6)	94·3 { 19·5 V. 74·8 N.	(83·2—93·6)	89·4 { 40·6 V. 48·8 N.	—	—
Solids in suspension	(9·8—29·2)	19·7 { 12·5 V. 7·2 N.	(4·9—15·9)	8·7 { 4·7 V. 4·0 N.	(4·0—9·3)	6·5 { 3·8 V. 2·7 N.	10·0 { 6·6 V. 3·4 N.	10·0 { 7·4 V. 2·6 N.
Solids in solution	(66·0—91·2)	75·7	(81·4—89·2)	85·7	(78·7—89·4)	82·9	—	—
Total alkalinity (by Methyl Orange), as H_2SO_4	(9·8—24·5)	17·1	(11·7—17·7)	14·2	(11·8—15·6)	13·9	27·2	20·4
Caustic alkalinity (by Phenol-phthaleïn), as H_2SO_4	(3·7—11·7)	6·1	(0·0 —1·4)	0·4	(0·0—0·0)	0·0	14·9	9·0
Total hardness (as $CaCO_3$)	(10·3—16·0)	14·2	(9·4—20·0)	15·4	(11·1—17·7)	12·1	—	4·0
Hardness after boiling (as $CaCO_3$)	(6·2—12·4)	8·5	(7·8—17·4)	11·5	(6·8—14·9)	10·4	—	1·7
Incubation (by smell)	——		——		4 failed out of 4.		—	Not done.
Dissolved oxygen taken up from tap-water at 18° C. *in 48 hours*	——		——		——		3·77	2·64
Dissolved oxygen taken up from tap-water at 18° C. *in 5 days*	(7·48—15·44)	10·91	(5·68—13·96)	9·77	(9·33—10·84)	9·91	13·14	10·62

The crude waste liquor from this works is thus considerably weaker than that from the main works. It contains much less suspended matter, and is much less "hard." The tank treatment reduces the suspended matter of the crude liquor from 19·7 to 8·7 parts per 100,000. The filters only remove a further small quantity of suspended matter from the tank liquor, and have practically no effect as regards the oxidisability of the liquor. The latter is more or less coloured and turbid, with a soapy and sometimes spent bleach smell.

A sample of the lime kier liquor from this works gave the following figures on analysis :

Chance sample of liquor, No. B. 25, from a *Lime kier* after 8 hours' boil with "grey cloth." Drawn Friday, May 30th, 1913; analysed June 4th.

Parts per 100,000.

Ammoniacal nitrogen - - - - - -	1·40
Total organic nitrogen - - - - - -	20·85
Total nitrogen (by Kjeldahl) - - - -	22·25
Oxygen absorbed from N/8 permanganate at 27° C. *in* 4 *hours* - - - - - - -	691·4
Total solids - - - - - - -	1,981·6 { 1497·2 V 484·4 N
Total alkalinity (by Methyl Orange) as H_2SO_4 -	361·8
Caustic alkalinity (by Phenol-phthaleïn), as H_2SO_4 - - - - - - - - -	82·4
Starch* - - - - - - - -	1,000·0 approx.
Dissolved oxygen taken up from tap-water at 18° C. *in* 48 *hours* - - - - - -	110·0
Dissolved oxygen taken up from tap-water at 18° C. *in* 5 *days* - - - - -	146·0 + *x*†

* Estimated by comparing the blue colour given with iodine against that given by a standard solution of potato starch.

† "+ *x*" means that all the oxygen in the mixture has been used up.

This liquor is excessively polluting. It is strongly alkaline from lime in solution and in suspension, contains much starch, and takes up dissolved oxygen at a great rate. On neutralisation it would, no doubt, give very high figures for permanent hardness.

Samples of the brook water drawn above and below the outfalls from this works, gave the following figures :

Samples of Brook waters. Drawn Thursday, May 30th, 1913.

Parts per 100,000.	B.17. *Brook water.* 70 yards above outfall. Analysed, June 2nd, 1913.	B.18. *Brook water.* 100 yards below outfall. Analysed, June 2nd, 1913.
Ammoniacal nitrogen - - - - -	0·425	0·078
Albuminoid nitrogen - - - - -	0·086	0·170
Nitrous nitrogen - - - - - -	0·00	0·00
Nitric nitrogen - - - - - -	0·480	0·063
Oxygen absorbed from N/8 permanganate at 27° C. *in* 4 *hours* - - - - - -	7·32	6·80
Oxygen absorbed from N/80 permanganate at 27° C. *in* 4 *hours* - - - - - -	2·31	3·15
Total solids - - - - - - -	101·2 { 48·4 V. 52·8 N.	86·8 { 34·4 V. 52·4 N.
Solids in suspension - - - - -	4·3 { 2·5 V. 1·8 N.	8·4 { 5·0 V. 3·4 N.
Solids in solution - - - - - -	96·9	78·4
Total hardness, as $CaCO_3$ - - - - - -	45·0	37·2
Hardness after boiling, as $CaCO_3$ - - -	42·7	—
Acidity, as H_2SO_4 - - - - - -	4·66	Alkaline
Oxygen in solution when analysed - - -	0·59	0·0
Dissolved oxygen taken up from tap-water at 18° C. in 5 *days* - - - - - -	3·64	3·60 + *x*
Arsenic (As)* - - - - - - -	7·6	3·5
NOTES - - - - - - -	Brownish and opalescent. Considerable amount of brown-coloured suspended matter. Strong earthy smell.	Turbid and brownish in appearance, with much fine brown suspended matter.

* The excessive amounts of arsenic found in the waters were due to another works in which arsenical mixtures were manufactured.

A chance sample of sludge, run from the tanks to lagoon on May 19th, 1913, was taken from the latter on May 29th.

Number of sample	B.22.	
Drawn	May 29th, 1913. (Put in ice, May 31st.)	
Analysis begun	June 6th, 1913.	
	Parts per cent	
Moisture	75·2	
Dry matter	24·8	
	100·0	
Residue left on ignition	12·5	
	Calculated on:	
	Wet sludge.	Dry matter.
Nitrogen (N_2)	0·16	0·65
Phosphoric acid (P_2O_5)	0·13	0·52
Sulphuric acid (SO_3)	0·11	
Carbonic acid (CO_2)	Not much.	
Silica and silicates (*i.e.*, matter insoluble in acid, ignited)	7·15	
Oxides of iron and aluminium ($Fe_2O_3 + Al_2O_3$)	0·42	
Lime (CaO)	2·05	8·2
Magnesia (MgO)	0·12	
Arsenic	0·008	
Lead, copper, tin, antimony	Absent.	

The sample was fresh at the date of analysis.

This sludge has but little value as a manure. It might, however, have some calorific value.

Calico Print Works, No. 13.

In reply to a request for information relating to the disposal of waste liquor from this mill, the Company were kind enough to send the following statement :—

"The process in use at the present time (November, 1910) has been followed for about two years, and is the successor of several different methods of treatment in use for the previous ten years. The earlier method of treatment, known as the Archbutt-Deeley process, was installed by Mather and Platt in 1896.

"In that year (1896) we started operations with four tanks supposed to be capable of treating 400,000 gallons a day, and five years later (1901) we adopted two more tanks on the same system, because of our inability to satisfy the Mersey and Irwell Joint Committee. These additional tanks did not enable us to get a very much better effluent, as the time necessary to allow the tanks to stand after treatment was too short. After much experimenting, extending over a period of three or four years, we adopted our present system of treatment, making use as far as possible of the plant already in existence, and we now describe the process of treatment in detail, as we have worked it since October, 1908.

"The various wash waters from the different departments are, for the purposes of treatment, divided into two groups which we name respectively 'Dirty' and 'Clean.' The 'dirty' water is such as contains soap, grease, colouring matters of various kinds, starch, gum, china clay and other finishing materials, and is collected from the bleaching, dyeing, printing and finishing departments. The 'clean' water is more or less colourless and contains either lime, soda, acid or other soluble and colourless chemicals, according to the time of the day, and is collected from the bleaching and dyeing departments only.

"We collect these two classes of water into two separate drains, named, respectively, the 'dirty' and 'clean' drains, and they are conducted to two different positions at the effluent treatment tanks. When caught at the outfall the 'dirty' water has an average composition of :—

(A.) Parts per 100,000.	"Dirty" water entering first tank.	Highest result.	Lowest result.
Total dissolved solids	125·0	188	112
Total dissolved solids (mineral)	50·7	68	48
Total dissolved solids (volatile)	74·2	120	64
Total suspended solids	47·8	76	24
Total suspended solids (mineral)	15·5	24	10
Total suspended solids (volatile)	32·1	51	14
Total solids (dissolved and suspended)	172·8	264	137

"We immediately add milk of lime and a solution of alumino-ferric and pass the crude liquor by its own gravity into Tank 1.

"The outlet from Tank 1, being at the bottom, about 6 feet from the surface, much of the highly coloured soap and grease is seen floating on the top of the tank, and we notice this material continues to float for about a day before it becomes of sufficient density to cause it to disappear from the surface and sink to the bottom of the tank. Passing from Tank 1 to Tank 2 by an outlet at the bottom of the dividing wall, the water deposits a considerable amount of highly coloured mud in the bottoms of both Tanks 1 and 2, and it then passes *over* the next dividing wall into Tank 3, again *over* a wall into 4, *over* into 5 and then *under* the dividing wall into 6. Tanks 1 and 2 naturally contain the largest deposit of sludge and are cleaned out more frequently than the others. The average composition of the effluent issuing from Tank 6 is :—

(B.) Parts per 100,000.	After treatment.	Highest result.	Lowest result.
Total dissolved solids - - - - - -	134·2		
Total dissolved solids (mineral) - - -	68·5		
Total dissolved solids (volatile) - - -	65·7		
Total suspended solids - - - - - -	17·8	25·7	12·8
Total suspended solids (mineral) - - -	7·1	8·5	—
Total suspended solids (volatile) - - -	10·7	17·1	5·7
Total solids (dissolved and suspended) - -	152·1	171·4	135·7

" At this stage the water, although still discoloured, is sufficiently advanced in its treatment to mix with the so-called 'clean' water carried into Tank 7 by the 'clean' drain from the bleach house and dye house

" The average composition of the 'clean' water is :—

(C.) Parts per 100,000.	Clean water.	Highest result.	Lowest result.
Total dissolved solids - - - - - -	80·7		
Total dissolved solids (mineral) - - -	46·4		
Total dissolved solids (volatile) - - -	35·0		
Total suspended solids - - - - - -	7·8	15·7	0
Total suspended solids (mineral) - - -	4·2	7·1	0
Total suspended solids (volatile) - - -	3·5	8·5	0
Total solids (dissolved and suspended) - -	88·5	137·1	67·1

" These two classes of water mix together in Tank 7, pass *under* the wall into Tank 8, and *over* the wall into the outfall sewer pipe which conducts the effluent to a point on the river about three-quarters of a mile below our works.

" The composition of the final effluent is :—

(D.) Parts per 100,000.	Final effluent.	Highest result.	Lowest result.
Total dissolved solids - - - - - -	113·5		
Total dissolved solids (mineral) - - -	59·2		
Total dissolved solids (volatile) - - -	54·2		
Total suspended solids - - - - - -	10·0	14·2	5·7
Total suspended solids (mineral) - - -	4·2	7·1	2·8
Total suspended solids (volatile) - - -	5·7	7·1	2·8
Total solids (dissolved and suspended) - -	123·5	138·5	108·5

" Our present addition of lime works out at 4⅕ grains per gallon, and of alumino-ferric at 10½ grains per gallon. Once a week we pump out the sludge from two or more of the tanks on to a filter bed of furnace ashes; we leave the sludge for several days to solidify and then we cart away to the cinder tip.

" It will be readily understood that a new plant would have been arranged more satisfactorily and more economically than ours, which was an adaptation of such appliances and arrangements as we found convenient after the abandonment of our previous system. This adaptation makes it rather difficult to furnish accurate figures of the cost of installation, but as far as possible we have given the cost of such material and plant as we make use of in our present method of treatment. We do not take into account the cost of any drains or sewers leading up to or away from the treatment works.

" It may be of interest to add that we bleach, dye, print and finish an average of 9 tons weight of cotton cloth per day.

" Annual cost of treatment for 500,000 gallons per 24 HOURS. Capital outlay estimated at £1,062.

	£
5 per cent. interest on £1,062 - - - - - - - - -	53
7½ per cent. depreciation and repairs - - - - - - -	80
Wages - - - - - - - - - - - - -	104
Steam for sludging, etc. - - - - - - - - -	60
36 tons lime - - - - - - - - - - -	28
90 tons alumino-ferric - - - - - - - - -	214
	£539

" This sum does not include any charge for rent, rates, insurance, general management, chemist's supervision and frequent analyses, carting sludge, etc."

The following analyses, which also relate to the Print Works No. 13, have been supplied by Mr. Frank Scudder. They relate to hourly samples drawn over a period of one working day.

	Chemical results expressed in parts per 100,000.	
	Before treatment.	After treatment.
Free and saline ammonia	0·06	0·06
Albuminoid ammonia	0·04	0·03
Oxygen absorbed :—		
(*a*) 3 minutes' test at 60° F.	5·40	5·71
(*b*) 4 hours' test at 60° F.	14·30	11·40
(*c*) After 4 days' incubation at 75·5° F. in sealed pipette :—		
(*a*) 3 minutes' test	6·31	4·2
(*b*) 4 hours' test	18·1	13·2
	In both samples there was a little starch present, as indicated by the iodine test, but after incubation no trace of starch was found.	
Action of HCl on effluent at 100° C. :—		
Insoluble in acid :—		
Mineral	None.	None.
Volatile	17·9	9·1
Total	17·9	9·1
Suspended solids :—		
Mineral	11·0	4·0
Volatile	9·4	4·4
Total	20·4	8·4
Composition of mineral suspended solids :—		
(*a*) Insoluble in HCl (SiO_2)	None.	None.
(*b*) Iron and alumina (Fe_2O_3, Al_2O_3)	2·5*	trace Al_2O_3
(*c*) Lime (as $CaCO_3$)	7·9	3·5
(*d*) Magnesia (MgO)	None.	None.
Soluble solids :—		
Mineral	59·74	74·00
Volatile	59·00	39·50
Total	118·74	113·50
Chlorides (as Cl)	12·40	19·20
Sulphates (as SO_3)	13·12	15·89
Insoluble in HCl (SiO_2)	2·00	1·50
Iron and alumina (Fe_2O_3, Al_2O_3)	2·74*	2·74*
Lime (CaO)	15·88	17·90
Magnesia (MgO)	3·68	2·70
Alkalinity :—		
(*a*) Free sulphuric acid (H_2SO_4) required to neutralise (*Phenol-phthaleïn*)	None.	None.
(*b*) Total sulphuric acid (H_2SO_4) required to neutralise (*Litmus* boiling)	21·4	None.
(*c*) Acidity expressed in terms of H_2SO_4 (*Litmus* cold, as indicator)	—	2·9
Transparency :—		
Millimetres depth seen through	20	35
Remarks	A dark reddish-brown turbid, slightly fluorescent liquid. Blue-black sediment.	A reddish brown turbid, slightly fluorescent liquid. Brown sediment.

* Mostly Al_2O_3.

Calico Print Works No. 14.

The following figures, which have been obtained from Tables given to us by Mr. Edward Halliwell, Chief Inspector to the Ribble Joint Committee, relate to a works at which the processes of printing, bleaching, and dyeing are carried out.

The mixed waste liquors are, in this case, allowed to flow through tanks which have a total capacity equal to the volume of waste liquor produced per working day.

	Parts per 100,000	
	Mixed crude liquor. Average of two chance samples.	Effluent from settling tanks. Average of five chance samples.
Unfiltered sample.		
Oxygen absorbed from N/80 permanganate in 3 minutes	3·25	1·35
Oxygen absorbed from N/80 permanganate in 4 hours	9·74	
Solids in suspension	57 { 26·5 V. 30·5 N.	7·3 { 4·1 V. 3·2 N.
Solids in solution	108 { 26 V. 82 N.	116 { 32 V. 84 N.
Filtered sample.		
Oxygen absorbed from N/80 permanganate in 3 minutes	1·63	
Oxygen absorbed from N/80 permanganate in 4 hours	4·8	

The three samples of tank effluent tested gave no smell of sulphuretted hydrogen on incubation.

Reference may also be made to another large print works in Lanarkshire, where, approximately, 1,250,000 gallons per day of mixed waste liquor from the bleach, print and dye houses are passed through a series of settling tanks having a total capacity of 700,000 gallons. Dr. J. T. Wilson, in a report to the Lanarkshire County Council, dated 1909, makes the following remarks with regard to the treatment at this works:—

> "The liquid, before treatment, is of a deep brownish red colour, turbid and opaque, capable of absorbing oxygen (from permanganate) to the extent of 12 parts per 100,000, whereas after treatment the colour is yellowish brown, transparent and slightly turbid, capable of absorbing oxygen to the extent of 1·4 parts per 100,000. These satisfactory results, however, are not always maintained."

Summary as regards Printing.

Practically the same remarks as were made in the case of dye works apply here also.

The foregoing analyses shew that the waste liquors from calico printing works, as usually carried on, are polluting, not only because of their suspended matter, but also because of the dissolved impurities which they contain.

Settlement in tanks, with or without the preliminary addition of chemicals, removes much of the impurity in suspension, but a liquid which cannot be called unobjectionable still remains.

This liquid is usually coloured, notwithstanding the use of precipitants; it contains a considerable quantity of colloidal matter, and it is liable to increase the hardness of water into which it is discharged. Halliwell, Jan. 27th, 1909, Question 27,878.

In a letter dated April 27th, 1911, Mr. Stowell stated that 156 samples of printworks effluent, drawn in the Mersey and Irwell district, gave an average of 5·3 parts of suspended matter per 100,000, and that 32 of these samples contained practically no suspended solid.

Taking all the foregoing data into account, we suggest that it is quite practicable to reduce the suspended matter in cotton printing waste to 6 parts per 100,000.

(3) *Bleaching.*

55. By far the greater part of the cotton cloth manufactured in this country is eached before being sold or exported; only a small proportion is sold as grey cloth.

In order to facilitate the weaving process the thread is run through a "sizing" solution, and the greater part of the matter so added, as well as the gummy matter naturally surrounding the cotton fibre, has to be removed before the cloth is bleached. This process is called "kiering" in the trade. It consists in boiling the cloth with either milk of lime or sodium carbonate solution, or first with one and then with the other, according to the cloth dealt with. The materials used in the sizing solution vary at almost every weaving shed, but common ingredients are starch, farina, sago, paraffin wax and china clay. Chloride of zinc or of aluminium is also added, to prevent the formation of moulds on the cloth in storing. The waste kier liquor contains these substances as well as the gummy matter of the cotton fibre.

The quantity of " size " used also varies according to the cloth which is being made. A fine fabric may have only 2 per cent. of size in it ; a coarse one over 100 per cent.

It has been said that frequently far more " size " is added to the thread than is necessary for its weaving, but we are informed that this is not so, and that where a cloth is being made for bleaching, the quantity of size is specially kept down by the weaver.

The removal of the size by the kier process results in a waste liquor which is by far the most polluting amongst those which go to make up the total waste. It is a yellowish brown ropy liquor of alkaline reaction and containing much starch and gummy matter in colloidal solution.

The waste acid and bleach waters, together with the general wash waters from a bleach works, serve to neutralise and dilute the kier liquor, but the total waste liquor from a bleach works always retains the kier liquor characteristics, except perhaps as regards alkalinity.

Average samples have been drawn at two bleach works, one where heavy goods and the other where light goods were being bleached.

Bleach Works No 15.

The goods dealt with at this works are sheetings and pillow-cases. The waste liquors and wash waters, with the exception of the kier liquor, are drained into a sump and pumped thence to the settling tanks. The kier liquor is pumped separately to the settling tanks in such a way as to divide it evenly amongst the other waste liquors and the wash-waters. The total flow of waste liquor from the works is about 300,000 gallons per working day.

There are three settling tanks, each of about 90,000 gallons capacity. They are used separately, about 10 hours quiescent settlement being usually allowed. One of the tanks is cleaned out every week, the sludge being run into a sump and then on to draining lagoons. When dry, it is carted away to a tip. Something like 30 to 40 tons of this dried sludge are removed every three weeks.

The average samples of crude liquor and final tank effluent drawn at this works gave the following results :—

Average figures of analysis of 4 sets of samples drawn on April 29th and 30th, May 1st and 2nd, 1913. The samples of crude waste and settled liquor (day samples) were average ones, the former being made up of samples drawn every half hour from 6.0 a.m. to 5 p.m., and the latter of samples drawn every quarter hour during the emptying of the tank.

Analysed May 1st, 2nd, 5th, 6th and 8th.

Parts per 100,000.

	Crude waste.		Settled liquor as discharged to river (day samples).		Settled liquor as discharged to river (chance night samples).	
Ammoniacal nitrogen - -	(0·05—0·16)	0·09	(0·04—0·19)	0·10	(0·02—0·02)	0·02
Albuminoid nitrogen - -	(0·57—0·63)	0·60	(0·20—0·68)	0·49	(0·47—0·72)	0·60
Total organic nitrogen -	(0·82—1·23)	1·06	(0·82—1·49)	1·07	(0·48—1·34)	1·07
Nitrous nitrogen - - -	(0·00—0·00)	0·00	(0·00—0·00)	0·00	(0·00—0·00)	0·00
Nitric nitrogen - - -	(0·33—0·67)	0·48	(0·33—0·70)	0·51	(0·25—0·39)	0·29
Total nitrogen (by Kjeldahl)	(1·61—1·65)	1·63	(1·28—1·88)	1·56	(0·73—1·65)	1·38
Oxygen absorbed from N/8 permanganate at 27° C. " *at once* " - - -	(6·96—12·70)	9·96	(4·00—13·70)	7·49	(7·07—13·70)	11·07
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours* - - - -	(29·60—36·60)	32·84	(11·50—30·80)	22·37	(17·90—29·60)	26·23
Total solids - - - -	(161·6—204·0)	185·8 { 93·2 V.* 92·6 N.	(126·0—188·8)	163·3 { 68·4 V. 94·9 N.	(150·0—185·2)	170·6 { 81·4 V. 89·2 N.
Solids in suspension - -	(21·4—51·2)	33·0 { 12·9 V. 20·1 N.	(6·3—13·2)	9·0 { 5·9 V. 3·1 N.	(5·4—9·3)	6·9 { 4·2 V. 2·7 N.
Solids in solution - -	(110·4—174·2)	152·8	(119·7—182·3)	154·3	(143·2—175·9)	163·5
Total alkalinity (by Methyl Orange), as H_2SO_4 - -	(30·10—35·82)	33·14	(2·14—20·78)	11·82	(19·34—31·24)	25·82
Caustic alkalinity (by Phenolphthaleïn), as H_2SO_4 -	(0·00—0·00)	0·00	(0·00—0·00)	0·00	(0·00—0·00)	0·00
Total hardness, as $CaCO_3$ -	(47·85—57·50)	53·59	(55·25—68·05)	60·71	(46·45—60·58)	52·91
Permanent hardness, as $CaCO_3$	(20·35—43·55)	44·19	(38·55—59·75)	48·08	(31·45—45·70)	37·90†
Dissolved oxygen taken up from tap-water at 18° C. *in 48 hours* - - -		14·30‡		11·30‡		9·25‡
Dissolved oxygen taken up from tap-water at 18° C. *in 5 days* - - - -	(28·4—36·4)	31·0	(13·50—27·8)	22·7	(21·9—31·3)	27·1

* V = Volatile. N = Non-volatile. † Average of 3 samples. ‡ One sample only.

It will be seen that the crude liquor is a very polluting liquor ; it contains over 30 parts of suspended matter, it is " hard," and it takes up a large quantity of oxygen from water. The tank treatment reduces the suspended matter to something like one-quarter of the amount present in the crude liquor, but hardly affects the figures for "hardness," or for absorption of oxygen.

Four chance samples of the final tank effluent from this works gave the following figures. They were the same in character as the average samples, but showed of course considerable variation in quality among themselves.

	Final effluent.		Final effluent.		Final effluent.		Final effluent.	
	No. 1.		No. 2.		No. 3.		No. 4.	
Sample drawn - - Sample analysed -	January 20th, 1911. 10.45 p.m. January 23rd.		January 24th, 1911. 12 noon. January 26th.		November 18th, 1913. 12 noon. November 20th.		Tuesday, Dec. 16th, 1913. 12 noon. December 18th.	
	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.	Original sample.	After filtration through paper.
Parts per 100,000.								
Ammoniacal nitrogen -	0·15	0·15	0·24	0·24	0·07		0·07	
Albuminoid nitrogen -	0·16	0·16	0·71	0·64	0·75		0·72	
Total organic nitrogen -	0·67		1·37		1·26		1·56	
Nitrous nitrogen - -	0·0		0·0		0·0		0·0	
Nitric nitrogen- - -	0·25		0·13		0·0		0·0	
Total nitrogen (by Kjeldahl) - - - -	1·07		1·74		1·33		1·63	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) at once -					3·59		3·33	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) in 4 hours	20·29	17·59	46·74	42·49	31·03		41·70	
Incubator test (by smell)	(*a*) Passed (slight odour of spent bleach). (*b*) When incubated with a few drops of sewage, the liquor had a slight odour of sewage.		(*a*) Passed (slight odour of spent bleach). (*b*) When incubated with a few drops of sewage, it became putrid, with H_2S.				Failed (unpleasant smell, but no H_2S).	
Dissolved oxygen taken up from water at 18° C. in 24 hours - - -	2·28	0·67	0·68	0·60				
Dissolved oxygen taken up from water at 18° C. in 48 hours - - -	9·6 + x †	5·41	12·8	5·84	10.0		21·2	
Dissolved oxygen taken up from water at 18° C. in 5 days - - - -	20·0 + x	15·46	36·4 + x	31·5	45·4	47·8*	50·1	37·4
Solids in suspension -	$12{\cdot}1\left\{\begin{array}{l}4{\cdot}9\ \text{V.}\\ 7{\cdot}2\ \text{N.}\end{array}\right.$ The Gooch filtrate was opalescent. By February 13th, more solids had come down, viz.: $6{\cdot}4\left\{\begin{array}{l}3{\cdot}5\ \text{V.}\\ 2{\cdot}9\ \text{N.}\end{array}\right.$ and the liquor was still somewhat opalescent.		$20.1\left\{\begin{array}{l}9{\cdot}4\ \text{V.}\\ 10{\cdot}7\ \text{N.}\end{array}\right.$ The Gooch filtration was difficult and the filtrate was opalescent. By February 14th more solids had come down, viz.: $9{\cdot}8\left\{\begin{array}{l}7{\cdot}0\ \text{V.}\\ 2{\cdot}8\ \text{N.}\end{array}\right.$ the filtrate still being rather opalescent.		$32{\cdot}0\left\{\begin{array}{l}17{\cdot}0\ \text{V.}\\ 15{\cdot}0\ \text{N.}\end{array}\right.$		$26{\cdot}6\left\{\begin{array}{l}10{\cdot}8\ \text{V.}\\ 15{\cdot}8\ \text{N.}\end{array}\right.$	
Total hardness (as $CaCO_3$)	44·0		53·9		70·0		60·0	
Permanent hardness (as $CaCO_3$) - - -	32·2		48·5		58·6		50·0	
Total alkalinity, expressed as H_2SO_4 (Me.O.) -					32·6 (no caustic alkalinity).		25·8 (no caustic alkalinity).	
"Free" chlorine (tested with iodide) - - -	0·0		Not tested.					
"Available" chlorine (tested with iodide and acid) -	0·0		Not tested.					
Notes - - - - -	Three bottles of this sample were received, which were mixed for analysis. The effluent was brownish and turbid, the suspended matter being very finely divided. Strong spent bleach odour. The paper filtrate became fairly clear as the filtration went on. February 21st, considerable froth on shaking bottle, which had been standing partly full.		There were three bottles of this sample also, which were mixed for the analysis. The effluent was very turbid and brown, with much fine sediment; strong spent bleach odour. The paper filtrate was almost clear, but still very brown. February 21st, much froth on shaking partly full bottle.		Brownish and turbid, with considerable very fine white suspended matter. Sweetish odour of spent bleach.		Brownish and turbid, with considerable fine white suspended matter.	

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* Estimated on December 3rd, from a bottle four-fifths full of sample.

† "+ x" means that all the oxygen in the mixture was used up.

All these samples contained much oxidizable matter in solution, as shown by their taking up large quantities of dissolved oxygen from water. They were also somewhat hard and they frothed considerably on shaking.

In order to gain some indication as to how far this type of effluent would be amenable to biological filtration, about 8 litres of a sample drawn on January 17th or 18th, 1914, were passed through a laboratory filter of matured clinker. The works' effluent—which was brown, colloidal and frothy—was first siphoned from the white deposit in each bottle.

The following short table shows the result of the filtration, as measured by the figures for "oxygen absorbed" from permanganate in 4 hours at 80° F. :—

Date, 1914.	Approximate range of temperature (°F.)*	Rate of Filtration in gallons per cubic yard per 24 hours.	"Oxygen absorbed" from N/8 permanganate at 80° F. in 4 hours.
January 21 - - -	42° to 44°·5	40	5·74
„ 22 - - -	42° „ 45°·0	26·5	6·67
„ 23 - - -	41° „ 43°·5	50	8·48
„ 24 - - -	39° „ 41°·0	40	11·35
„ 26 - - -	39° „ 45°·5	28	8·07
„ 27 - - -	44° „ 47°·5	21	3·59
„ 28 - - -	44° „ 47°	41	5·27
„ 29 - - -	47°·5 „ 51°	34	4·42
	Original	Effluent - - -	- - 35·0

* These were the temperatures of an adjoining room, which may have been a trifle the warmer.

These biological filter effluents were brownish and opalescent, and still contained a slight trace of starch.

The purification, as calculated on the "oxygen absorbed" from permanganate, averaged 81 per cent., at an average rate of filtration of 35 gallons per cubic yard per 24 hours. Broadly speaking, the actual biological oxidation effected was about half what might have been expected with a sewage of average strength. Further experiments, both in the laboratory and on a large scale, are required here.

Samples of the strong lime and soda kier liquors, analysed separately, gave the following figures :—

Chance Samples of Crude Kier Liquors.—Drawn, May 2nd, 1913.
Analysed, May 19th.

Parts per 100,000.

	Liquor from a Lime Kier.	Liquor from a Soda-ash Kier.
Ammoniacal nitrogen - - - - - - -	1·24	0·09
Total organic nitrogen - - - - - - -	36·42	3·97
Total nitrogen (by Kjeldahl) - - - - - -	37·66	4·06
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	655·4	132.1
Total solids - - - - - - - - -	2302·6 { 1680·2 V. 622·4 N.	1271·6 { 416·4 V. 855·2 N.
Solids in suspension - - - - - - -	*165·2 { 151·2 V. 14·0 N.	*32·4 { 26·0 V. 6·4 N.
Solids in solution - - - - - - - -	2137·4	1239·2
Total alkalinity (by Methyl Orange) as H_2SO_4 - -	361·9	727·2
Caustic alkalinity (by Phenol-phthaleïn) as H_2SO_4 - -	112·9	293·8
Starch† - - - - - - - - - -	280·0	0·0
Dissolved oxygen taken up from tap water at 18° C. *in 48 hours* - - - - - - - - -	35·5 + x‡	5·25
Dissolved oxygen taken up from tap water at 18° C. *in 7 days* - - - - - - - - -	70 + x‡	61·6
Remarks - - - - - - - - -	Thick lemon-yellow liquor, with much limey deposit. Strong sugary smell.	Dark brown liquor, with a considerable amount of flocculent suspended matter. Strong burnt sugar smell.

* These figures are approximate only. The nature of the liquors is against an accurate estimation.

† Estimated by comparing the blue colour given with iodine against that given by a standard solution potato starch.

‡ "+ x" means that all the oxygen in the mixture was used up.

The kier liquors from a Bleach works of this kind are thus very polluting liquors, containing a large amount of dissolved and colloidal organic matter, and taking up oxygen from water at a rapid rate.

The following figures relating to samples of the river water above and below the effluent outfall will also be of interest. They show that the admixture of the effluent has distinctly lowered the quality of the water, even though the latter was far from pure above the effluent outfall.

Samples of river waters.—Drawn May 2nd, 1913, at 2.30 p.m. The river was well above summer level.

Parts per 100,000.

	River water taken about 100 yards above the works. Analysed, May 5th.		River water taken about 300 yards below the works outfall.* Analysed, May 6th.	
Ammoniacal nitrogen	0·13		0·17	
Albuminoid nitrogen	0·07		0·08	
Nitrous nitrogen	0·00		0·07	
Nitric nitrogen	0·31		0·07	
	Original sample.	Sample filtered through paper.	Original sample.	Sample filtered through paper.
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	1·29	0·76	1·97	1·64
Oxygen absorbed from N/80 permanganate at 27° C. in 4 hours	0·67	0·42	0·92	0·71
Total solids	37·6 14·8 V. 22·8 N.		83·2 17·2 V. 66·0 N.	
Solids in suspension	†4·1 2·4 V. 1·7 N.		5·0 2·7 V. 2·3 N.	
Solids in solution	33·5		78·2	
Hardness (as $CaCO_3$)	23·6		20·7	
	Original sample.	Sample filtered through paper.	Original sample.	Sample filtered through paper.
Dissolved oxygen taken up from tap water at 18° C. in 4 days	1·00	0·63	1·73	1·35
Oxygen in solution when analysed	0·47		0·34	

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* A 90,000 gallon tank of settled liquor was emptied between 1.30 p.m. and 3.30 p.m. The sample of river water therefore contains this liquor.

† These solids, examined under the microscope, appeared to consist of decayed vegetable matter and white fibre.

A chance sample of sludge was taken on April 30th, 1913, from a tank which had run for the regular period of three weeks and which was just about to be discharged to a lagoon.

Number of Sample	No. 6.	
Drawn	April 30th, 1913.	
Analysis begun	June 12th, 1913.	
	Parts per cent.	
Moisture	74·4	
Dry matter	25·6	
	100·0	
Residue left on ignition	20·2	
	Calculated on :	
	Wet Sludge.	Dry Matter.
Nitrogen (N_2)	0·078	0·30
Phosphoric Acid (P_2O_5)	0·083	0·3
Sulphuric Acid (SO_3)	0·0	
Carbonic Acid (CO_2)	Much.	
Silica and Silicates	14·05	
Oxide of Iron and Alumina ($Fe_2O_3 + Al_2O_3$)	0·37	
Lime (CaO)	3·78	
Magnesia (Mg O)	0·12	
Arsenic (As)	Mere trace, if any.	

This sample had become very foul-smelling when analysed—six weeks after being drawn.

Bleach Works No. 16.

Very light cloths, manufactured for the Indian market, are dealt with here. Only a small quantity of size has, therefore, to be removed before bleaching and the kier liquor is comparatively weak in consequence.

The total volume of waste liquor is about 200,000 gallons per working day of 10 hours, some 5 per cent. of this being soda or lime kier liquor.

All the liquors are discharged into one drainage system and clarified in tanks and settling ponds before being discharged into a small tributary of the Irwell.

There are three settling tanks, each having a capacity of 90,000 gallons. They are fitted with elaborate baffling walls and coke screens and they are used in parallel.

The tank liquor is passed through 4 or 5 small settling ponds, used in series, before flowing into the brook.

The tanks are sludged every three or four months, the sludge being dried in lagoons and then carted to a tip.

Average figures of analysis of 4 sets of Average Samples drawn on May 6th, 7th, 8th and 9th, 1913. Samples were drawn every half hour while the works were running (5.45 a.m. to 4.15 p.m.)

Parts per 100,000.	Crude waste.		Settled liquor as leaving tanks.		Final liquor as entering brook.		Chance Sample of Final Effluent. Drawn Tuesday, January 27th, 1914. Analysed January 29th.
Ammoniacal nitrogen	(0·05 — 0·10)	0·09	(0·01 — 0·05)	0·03	(0·01 — 0·03)	0·02	0·09
Albuminoid nitrogen	(0·42 — 0·47)	0·44	(0·38 — 0·53)	0·44	(0·29 — 0·43)	0·36	0·42
Total organic nitrogen	(0·81 — 1·28)	0·97	(0·72 — 1·17)	0·91	(0·43 — 0·98)	0·73	0·81
Nitrous nitrogen	(0·00 — 0·00)	0·00	(0·00 — 0·00)	0·00	(0·00 — 0·00)	0·00	0·0
Nitric nitrogen	(0·13 — 0·34)	0·25	(0·17 — 0·35)	0·29	(0·15 — 0·32)	0·21	0·23
Total nitrogen (by Kjeldahl)	(1·11 — 1·51)	1·28	(1·09 — 1·35)	1·22	(0·76 — 1·16)	0·96	1·13
Oxygen absorbed from N/8 permanganate at 27° C. "at once"	(6·00 — 7·60)	6·74	(6·16 — 8·26)	7·02	(4·94 — 7·22)	6·13	1·69
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	(23·30 — 30·90)	26·38	(21·50 — 25·90)	23·43	(14·14 — 21·20)	17·51	22·0
Incubator test (by smell)	——		——		4 failed out of 4.		Passed
Total solids	(174·8—211·2)	196·6 { 94·0 V.* 102·6 N.	(139·6—153·6)	147·2 { 77·4 V. 69·8 N.	(106·4—130·0)	118·5 { 58·3 V 60·2 N	
Solids in suspension	(41·8— 70·4)	56·8 { 16·6 V. 40·2 N.	(18·4— 27·6)	24·8 { 7·3 V. 17·5 N.	(11·8— 16·2)	13·9 { 5·5 V 8·4 N	14·8 { 4·2 V 10·6 N
Solids in solution	(133·0 —141·1)	137·5	(114·0 —135·2)	122·5	(90·2 —117·0)	104·3	——
Total alkalinity (Methyl Orange) as H_2SO_4	(46·58— 80·24)	65·75	(33·90— 39·40)	36·08	(22·21— 32·24)	26·51	59·1
Caustic alkalinity (Phenol-phthaleïn) as H_2SO_4	(7·88— 32·96)	19·17	(0·00— 4·30)	1·08	(0·00— 0·00)	0·00	36·8
Total hardness (as $CaCO_3$)	(23·93— 85·70)	44·40	(25·00— 37·90)	33·69	(31·03— 39·07)	35·21	55·3
Hardness after boiling (as $CaCO_3$)	——		——		(13·02— 22·15)	18·90	28·6
Dissolved oxygen taken up from tap-water at 18° C. in 48 hours		11·70†		4·30†		6·75†	9·9
Dissolved oxygen taken up from tap-water at 18° C. in 5 days	(25·1 — 29·0)	27·0	(14·2 — 22·9)	19·0	(15·4 — 23·5)	19·0	29·4 Paper filtered 22·6

*V. = volatile. N. = non-volatile. † One sample only.

If the above figures are compared with those given for the waste liquors from Bleach works No. 15, it will be seen that they are very similar in every respect except as regards strength.

The final effluents are both brownish and rather turbid alkaline liquors, which contain little nitrogen but take up very considerable amounts of oxygen from permanganate and from water. A considerable quantity of starchy matter is, of course, to be found in them. The effluent from works No. 16 is about two-thirds as strong as that from No. 15.

In order to test whether the absorption of dissolved oxygen by the liquors was due mainly to the solids in suspension or to the matter in solution, samples Nos. 22, 23 and 23a were filtered through Swedish filter paper and the absorption of dissolved oxygen from tap water in 6 days, both by the original and the paper-filtered samples, was estimated :—

	Crude waste. No. 22.	Settled liquor. No. 23	Final liquor. No. 23A.
Suspended solids - - - - - -	56·8	24·8	13·9
Dissolved oxygen taken up at 18° C in 6 days :—			
Original sample - - - - - - - -	30·1	27·5	23·8
Paper-filtered sample - - - - -	20·5	20·5	17·7

It is thus evident that, as in the case of the effluent from works No. 15, the absorption is mainly due to the matter in solution, though a considerable proportion is also due to the suspended solids.

The following figures of analysis for the strong kier liquors from works No. 16 serve to show the reason for this difference in strength, when they are compared with those given for the kier liquor from works No. 15.

It will be noted that although these liquors are derived from the kiering of very light cloth, they are yet capable of taking up oxygen from water at a great rate and so doing much injury to a stream.

CHANCE SAMPLES OF CRUDE KIER LIQUORS.—DRAWN FRIDAY, MAY 9TH, 6.0 A.M. Analysed May 21st.

Parts per 100,000.

	No. 24. Liquor from a Lime Kier.	No. 25. Liquor from a Soda-ash Kier.
Ammoniacal nitrogen - - - - - - - - -	0·40	0·15
Total organic nitrogen - - - - - - - -	5·80	1·45
Total nitrogen (by Kjeldahl) - - - - - - -	6·20	1·60
Oxygen absorbed from N/8 Permanganate at 27° C. *in* 4 *hours*	216·6	76·6
Total solids - - - - - - - - -	640·8 { 492·4 V. 148·4 N.	888·8 { 256·8 V. 632·0 N.
Total alkalinity (by Methyl Orange) as H_2SO_4 - - -	123·6	559·6
Caustic alkalinity (by Phenol-phthaleïn) as H_2SO_4 - -	48·4	218·6
Starch - - - - - - - - - - -	150·0	0·0
Dissolved oxygen taken up from tap-water at 18°C. *in* 48 *hours*	24·7	14·0
Dissolved oxygen taken up from tap-water at 18° C. *in* 5 *days*	81·8	69·4

The Purification of Kier Liquors.

We have made a number of laboratory experiments on the biological purification of kier liquors, which may be shortly summarized. The samples of kier liquor—both lime and soda—were kindly supplied by a large Bleaching Company.

(1) The caustic alkali of the kier liquor should be converted into carbonate before biological filtration is attempted. This "carbonation" can be effected either by digestion of the liquor with sewage (septic tank) sludge, or by passing furnace gases through it. In these laboratory experiments* both processes required about 48 hours, but the gas method could no doubt be applied quickly in practice by the use of suitable percolating towers. Still, digestion with sludge appears to be the better plan, if practicable, because not only is the caustic alkali carbonated, but organic compounds more or less resistant to oxidation, like starch, are hydrolyzed in the process and the liquid can then be treated more successfully on biological filters. This latter method was first suggested many years ago by Naylor.†

The volume of the sludge would, of course, be continuously augmented by the deposition of carbonate of lime from the kier liquors; how far this would influence its efficiency, as time went on, could only be determined by actual trial.

(2) Several experiments have shown that, after standing for 48 hours in contact with septic tank sludge, a mixture of lime and soda ash liquors, undiluted, giving a figure of 230 for "oxygen absorbed" in 4 hours, can be converted into an effluent with a 4 hours' figure of 22 by biological filtration, at the rate of about 20 gallons per cubic yard per 24 hours. Further filtration of this effluent produces but little improvement.

(3) As might be expected, fresh kier liquor is much harder to purify than a sample which has been kept for some weeks.

(4) The residual organic matter of the biological filter effluent from kier liquor is much more readily oxidized by permanganate than by dissolved oxygen; thus, a filtrate with a 4 hours permanganate figure of 10·4 took up only 1·2 parts of dissolved oxygen from water in 3 days.

If this liquor which has been for a sufficient length of time in contact with sewage sludge is considerably diluted, prior to biological filtration (though still remaining strong, organically, after the dilution), quite a good effluent can be obtained. This is exemplified by the following experiments:—

1,000 c.c. of a sample of mixed lime and soda liquors were digested over 100 grms. of septic tank sludge (which contained a considerable amount of brewery refuse) for 48 hours at about 20° C. At the end of that time the caustic alkali had disappeared. 400 c.c of the liquor were then diluted with 1,600 c.c. of tap water (a dilution of 1 to 4) and the mixture was biologically filtered at the rate of 80 gallons per cubic yard per 24 hours. This gave a yellowish, slightly turbid filtrate, with a faint musty smell. The analytical figures for the two liquors were:—

Parts per 100,000 - - - -	Digested liquor, before filtration. (A.)	Biological filter effluent. (B.)
Ammoniacal nitrogen - - - - -	1·2	—
"Oxygen absorbed" from N/8 permanganate in 4 hours at 27° C. - - - - -	40·1	4·8
Nitric nitrogen - - - - - -	—	0·5 approx.

The above filtrate (B) was again passed through the filter at the rate of 56 gallons per cubic yard per 24 hours. This yielded a bright yellow filtrate, of clean smell. After a small quantity of suspended solids had been removed by filtration through paper, this second filtrate (C) showed the following analysis:—

Parts per 100,000.

Ammoniacal nitrogen - - - - - - - - - - -	0·28
Albuminoid nitrogen - - - - - - - - - - -	0·36
Nitrous nitrogen - - - - - - - - - - - -	0·0
Nitric nitrogen - - - - - - - - - - - -	0·48
"Oxygen absorbed" from N/8 permanganate at 27° C. at once - - - - -	0·70
"Oxygen absorbed" from N/8 permanganate at 27° C. in 4 hours - - -	3·10
Dissolved oxygen taken up from water at 18° C. in 5 days. - - - - - -	0·50
Incubator test - - - - - - - - - - - - -	Passed.

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* Carbonic acid from a Kipp apparatus was used here as representing furnace gases.

† *Trades Waste*, by W. Naylor (1902) p. 156.

A chance sample of sludge was taken from a lagoon at Bleach Works No. 16 during very rainy weather; the sample was consequently rather wet. No china clay is used at this works and hardly any starch.

Number of Sample	No. 34.	
Drawn	Probably May 12th,1913 (in ice May 13th).	
Analysis begun	June 12th.	
	Parts per cent.	
Moisture	78 0	
Dry Matter	22·0	
	100·0	
Residue left on ignition	20·2	
	Calculated on :	
	Wet Sludge.	Dry Matter.
Nitrogen (N_2)	0·013	
Phosphoric Acid (P_2O_5)	0·34	
Sulphuric Acid (SO_3)	0·17	
Carbonic Acid (CO_2)	Much.	
Silica and Silicates (ignited)	0·82	
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$)	0·47	
Lime (CaO)	10·60	
Magnesia (MgO)	0·45	
Arsenic (As)	Mere trace.	

The sample was quite fresh at the time of analysis. Consisting, as it did, mainly of carbonate of lime, this sludge might be applied with advantage to land.

Samples of brook water drawn above and below the outfall from works No. 16 gave the following figures on analysis:—

SAMPLES OF BROOK-WATERS.—DRAWN FRIDAY, MAY 9TH, 1913. Parts per 100,000.

	No. 27. *Brook water*—above works. Analysed May 15th.	No. 28. *Brook water*, 100 yards below outfall. The brook is small (5–6 feet across), but rapid; it was very much discoloured by the effluent. Analysed May 15th.	
Parts per 100,000.		Original sample.	Sample filtered through paper.
Ammoniacal nitrogen	0·008	—	0·031
Albuminoid nitrogen	0·013	—	0·102
Nitrous nitrogen	0·00	—	—
Nitric nitrogen	0·095	—	0·087
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	—	4·23	3·95
Oxygen absorbed from N/80 permanganate at 27° C. *in 4 hours*	0·30	2·01	1·90
Incubator test (by smell)	—	—	Failed; H_2S.
Chlorine	0·82	3·98	—
Total solids	14·8 { 6·8 V. 8·0 N.	47·6 { 22·8 V. 24·8 N.	— —
Solids in suspension	1·1 { 0·6 V. 0·5 N.	6·9 { 3·2 V. 3·7 N.	— —
Solids in solution	13·7	40·7	—
Hardness (as $CaCO_3$)	10·6	—	16·9
Dissolved oxygen taken up from tap-water at 18° C. *in 5 days*	0·14	6·64	2·86
Oxygen in solution when analysed	0·82	0·08	—

The admixture with the effluent thus converted a clean water, in which trout were plentiful, into a very turbid liquid which took up over 6 parts of dissolved oxygen in 5 days.

Summary as regards Bleach Waste.

It is clear that the waste liquor from cotton bleach works must be classed in a different category from the waste liquors from cotton dyeing and printing works.

If the separate wastes of which it is made up are not carefully mixed together, it may contain free caustic alkali and so be highly injurious to fish life. It takes up dissolved oxygen from water rapidly, and consequently brings about objectionable conditions in a stream unless the dilution is very great.

Its objectionable quality is due mainly to the kier liquor which it contains, and, for this reason, we think that every effort should be made to separate this liquor with the acid water from the bleach vat and send the mixture to the nearest sewers. Kier liquor is amenable to biological purification and will not, therefore, interfere with the purification of the sewage with which it is mixed, unless it is present in preponderating quantity.

We know of no method of purifying by itself the waste liquor from cotton bleach works which can be called reasonable and practicable at the present time.

Reduction of the suspended solids, though it still leaves an exceedingly polluting liquid, effects, however, some improvement in the waste, and we think that clarification down to 6 parts of suspended matter might reasonably be asked for in the case of most bleach works effluents.

In further support of this opinion we may give the following additional data.

A hundred and eighteen samples of bleach works effluent, taken by the Mersey and Irwell Rivers Committee, gave an average of 5·0 parts per 100,000 of suspended matter, 28 of these containing practically no suspended solids.

Eight samples of a bleach works effluent, taken by Mr. Halliwell for the Ribble Joint Committee, gave an average of 3·1 parts per 100,000, the range being from 1·2 to 5·6.

(4) *Cotton-Waste Bleaching.*

56. Waste bleaching is a small and somewhat special branch of the cotton trade.

It consists in the cleaning and bleaching of waste cotton from spinning mills and sheds, in order that it may be made into gun-cotton, etc.

The waste, which is usually dirty and somewhat greasy, is boiled under pressure with dilute caustic soda, then bleached and finally dried.

A strongly alkaline and very polluting kier liquor is produced.

The mixed effluent from a waste bleacher's works is similar in character to that produced at an ordinary bleach works, except that it is soapy and more likely to contain free caustic alkali.

In some cases the cotton waste is first treated with a solvent for the removal of grease. This should always be done where greasy waste has to be dealt with.

The remarks made in the summary relating to bleach waste apply here also.

We have not ourselves examined any samples of effluent from cotton waste bleach works, but 28 samples taken by the Mersey and Irwell Rivers Committee gave an average of 6·0 parts per 100,000 of suspended matter. It would appear, therefore, that clarification down to this figure might be a reasonable requirement.

The Woollen Industry.

57. The principal steps in the manufacture of woollen goods are as follows:—

(1) The grease which occurs naturally in the wool is removed by washing. This process is called wool washing or wool scouring.

(2) The scoured wool is carded and combed.

(3) The combed wool is spun into yarn.

(4) The yarn is scoured, to remove the oil added before spinning. This process is called yarn scouring.

(5) The yarn is woven into cloth.

(6) The cloth is washed. This process is called piece scouring.

(7) The cloth is milled and finished.

If coloured yarn or cloth is required, the wool is dyed either after the scouring process (wool dyeing), the combing process (hank dyeing), the spinning process (yarn dyeing), or the weaving process (piece dyeing).

At a given mill any one or all of the above processes may be carried out. In practice, a number of different combinations are to be found.

In some mills, calf's hair forms the raw material, while in others the wool may be mixed and spun with cotton or silk.

58. The chief centres of the woollen industry are the West Riding of Yorkshire, the Galashiels district in Scotland, Lancashire, and Gloucestershire.

The mills are situated in both urban and rural districts.

Comparatively large volumes of clear water are required in all the stages of the manufacture.

Polluting waste waters are derived from the following processes:—

(1) Wool scouring.
(2) Yarn scouring.
(3) Piece scouring.
(4) Dyeing.
(5) Milling and finishing.

The wool scouring liquor is by far the most polluting of these waste waters. The processes of piece and yarn scouring, with the rinsing waters, usually give rise to the largest volumes of waste liquor.

Polluting waste liquors are also produced in the scouring and milling of blankets, and in the carbonizing process carried out at many mills where shoddy is dealt with.

59. The commonest waste liquors or combinations of waste liquors which may be found at any one mill are as follows:—

1. Dye liquor.
2. Piece scouring liquor.
3. Piece scouring and dye liquors.
4. Wool scouring, piece (sometimes yarn) scouring, and dye liquors.
5. Wool scouring liquor.
6. Yarn scouring and dye liquors.
7. Wool scouring and piece (sometimes yarn) scouring liquors.
8. Yarn scouring and dye liquors.
9. Wool scouring and dye liquors.
10. Blanket scouring and milling liquors.
11. Dyeing and mercerizing liquors.
12. Carbonizing, scouring and dye liquors.

In this list the waste liquors or the combinations of waste liquors are given, as far as possible, in the order of the frequency of their occurrence in practice.

All the waste liquors produced in connection with the woollen industry are undesirable in streams because of the dissolved impurity which they contain, as well as through the suspended matter which they carry with them.

Except in the case of wool scouring liquor, however, the dissolved impurity is largely inorganic, and we are inclined to think that the chief objection to the discharge of the liquid portion of these waste liquors is on account of their "hardness."

On the other hand, except in the case of dye liquor, the impurity in suspension or colloidal solution, being of a greasy nature, is exceedingly objectionable in any stream.

60. In dealing with the waste liquors from woollen mills, we have considered it sufficient to refer specially to the following liquors or combinations of liquors:—

(1) Dyeing.
(2) Yarn, piece and blanket scouring liquors.
(3) Piece and yarn scouring liquor with dye liquor.
(4) Wool scouring, piece or yarn scouring and dye liquors.
(5) Wool scouring and piece or yarn scouring liquors.

Wool scouring liquor, occurring alone, is dealt with in Section III of this Report.

(1) *Dyeing (except with Indigo) in the Woollen Trade.*

61. Waste dye liquor is a mixture of the spent dye solution from the dye vats and the water used for washing the wool, yarn or cloth, after it has been taken from the dye vat.

Since a number of different dyes and mordants are used at different works, and in many cases at one and the same works, the waste dye liquor is of very variable composition from a chemical point of view. As a rule, however, the dye and mordant solutions are kept in use until the active substances which they contain are almost spent. For this reason, most waste dye liquors may be looked upon as being similar, so far as their practical purification is concerned.

In general terms they may be described as liquors containing a large quantity of matter, mainly inorganic, in solution, and carrying a considerable quantity of matter, largely wool fibre, in suspension. They are coloured, more or less strongly, with the dye or dyes which are being used at the mill; they are usually acid or alkaline in reaction (more frequently acid), and they are nearly always "hard."

They may contain small quantities of poisonous substances, *e.g.*, potassium bichromate, when these are used in the dyeing process. The spent dye solution is usually hot when discharged.

It is practicable to remove the greater part of the suspended impurity from these dye liquors by settlement in tanks, especially if precipitants are added. In the latter case much of the colouring matter is removed at the same time.

The following varieties of treatment are in use at the present time:—

(*a*) Precipitation followed by settlement and straining filtration.

(*b*) Settlement alone, or followed by straining filtration.

In our opinion the practicable object to be aimed at, for the time being, in the purification of dye liquors is to remove the greater part of the suspended matter, together with any free acid or any large excess of alkali, without greatly increasing the hardness of the clarified liquor.

Decolourization, though desirable, is in many cases only to be attained at high cost.

As regards the removal of suspended matter and colour, the best results are obtained when precipitation is adopted, but the use of precipitants, and especially of lime alone, is liable to result in a serious increase of permanent hardness. For this reason we think that precipitants should be selected with great care and used sparingly.

In particular cases the effluent can be used again with advantage. We doubt whether this point has been sufficiently considered by manufacturers.

(*a*) Precipitation, Settlement, and Straining Filtration.—Dye Works, No. 17.

The dye liquor at this mill is derived from piece dyeing. Aniline dyes are used, together with myrabolans extract, salts of iron, potassium bichromate and sulphuric acid.

The water supply is taken from the town mains.

The total volume of waste liquor is from 30,000 to 40,000 gallons per working day.

The purification plant is the Mackey-Akeroyd apparatus. We have inspected it on two occasions.

The waste liquors are first pumped from a collecting sump to an overhead tank, called the equalizing tank, where lime is added. The capacity of this tank is 10,500 gallons. The quantity of lime added varies according to the degree of acidity of the dye liquor; on the average, it amounts to about 35 parts per 100,000.

The limed liquor overflowing from the equalizing tank is conveyed by means of a pipe to the lower end of a large cylindrical boiler shell, laid at an angle of 12 degrees from the ground level. The boiler shell is 28 feet long and 7 feet 6 inches in diameter; its capacity is 7,700 gallons.

The settlement takes place as the liquor rises slowly in this tank, and the partially clarified liquor issuing from it is finally passed upwards through 9 feet of coke, from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches in diameter, contained in another boiler shell (6 feet 6 inches in diameter and 12 feet high), set vertically on end.

The coke is held in position by means of a false bottom, set 18 inches above the bottom end of the boiler.

Any sludge which collects in the space under the coke is removed once a day by means of a valve.

The bulk of the sludge which collects in the larger boiler shell is run off periodically, drained on sludge filters, and finally tipped.

The following analysis shows the character of a chance sample of effluent after the treatment by the Mackey-Akeroyd process :—

DYE WORKS No. 17.

	Treated effluent.	
Sample drawn	Wednesday, January 14th, 1914, 12.15 noon.	
Sample analysed	January 16th.	
Parts per 100,000.	Original sample.	After filtration through paper
Ammoniacal nitrogen	0·29	
Albuminoid nitrogen	0·21	
Total organic nitrogen	0·25	
Nitrous nitrogen	0·0	
Nitric nitrogen	0·34	
Total nitrogen (Kjeldahl)	0·88	
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.) at once	1·73	
Ditto ditto in 4 hours	11·20	10·78
Incubator test (by smell)	Failed (putrid ; H_2S.)	
Dissolved oxygen taken up from water at 18° C. (65° F.) in 3 days	5·14	
Ditto ditto in 5 days	13·6	14·1
Solids in suspension	2·1 { 1·0 V. 1·1 N.	
Total hardness (as $CaCO_3$)	76·6	
Permanent hardness (as $CaCO_3$)	76·6	
Total alkalinity, as H_2SO_4 (Me.O)	11·8 (only very slightly alkaline to phenol-phthaleïn).	
Notes	Brownish and opalescent, with a little fine suspended solid. Slight soapy smell.	

The following analytical results have been taken from tables of figures given to us by Dr. H. Maclean Wilson, Chief Inspector to the West Riding Rivers' Board. They refer to a set of average samples drawn from 10.20 a.m. to 4.25 p.m. on June 16th, 1908.

Dye Works, No. 17.

	Parts per 100,000.			
	Crude waste liquor.	Equalizing tank liquor.	Liquor from settling tank.	Filter effluent.
Parts per 100,000.				
Ammoniacal nitrogen - - -	0·30	0·35	0·30	0·27
Albuminoid nitrogen (Wanklyn) -	0·54	0·31	0·26	0·23
Organic nitrogen (Kjeldahl) - -	1·41	0·80	0·65	0·66
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F. -	14·30	6·90	5·00	4·85
Alkalinity (as $CaCO_3$) - - -	—	56·0	23·5	23·0
Acidity (as H_2SO_4) - - -	24·5	—	—	—
Hardness :—				
Temporary - - - -	10·0	0·00	18·0	17·7
Permanent - - - -	65·7	221·5	167·7	150·0
Total - - - -	75·7	221·5	185·7	167·7
Solids in suspension (dried at 100° C.) - - - - -	14·8 (ash 1·65)	32·5 (ash 24·5)	1·30 (ash 1·0)	0·96 (ash 0·72)
Solids in solution (dried at 100° C.)	208·8 (ash 155·6)	326·0 (ash 306·4)	294·0 (ash 256·0)	290·0 (ash 259·4)
Total solids - - -	223·6	358·5	295·3	290·96

Analysis of Chance Samples of the Sludge produced by the Mackey-Akeroyd Process.

	Air dried sludge.	
Sample collected.	June 16th, 1908.	September 1st, 1908.
Calculated on the moist sludge.		
Moisture - - - - - - - -	91·26	84·25
Organic and volatile matter - - - - -	4·34	4·36
Ash - - - - - - - - -	4·40	11·39
	100·00	100·00
Calculated on the dry solids.		
Organic and volatile matter - - - - -	49·65	27·67
Ash - - - - - - - - -	50·35	72·33
	100·00	100·00
Nitrogen (Kjeldahl) - - - - - - -	1·83	1·22
Fat (after acidification) - - - - - -	3·77	2·16
Lime (CaO) - - - - - - - -	—	26·00

The following analytical figures relating to this mill were handed in by the representatives of the West Riding of Yorkshire Mill Owners' and Occupiers' Association.

They refer to average samples taken every hour over a working day.

DYE WORKS, No. 17.

	Parts per 100,000.			
	Dye liquors before treatment.		Filter effluent.	
Appearance of sample.	Blueish.		Pale green.	
Solids in suspension	15·6		1·2	
Loss on ignition		14·4		0·4
Ash		1·2		0·8
Solids in solution	145·4		155·0	
Loss on ignition		72·4		22·0
Ash		73·0		133·0
Alkalinity, in terms of H_2SO_4	31·9		10·3	
Acidity, in terms of H_2SO_4	—		—	
Hardness (total)	49·0		90·0	
Fatty matter (extracted by ether)	1·6		None.	

It will be seen that the effect of the process is to remove the greater part of the suspended matter contained in the dye liquors, but, at the same time, to increase the dissolved matter appreciably, and the hardness very materially.

DYE WORKS, No. 18.

Another plant now in use for the purification of dye waters alone may also be referred to, namely, that devised by Mr. Thomas Waite, of Bradford. This is a special apparatus in which the waste liquors are precipitated, settled and filtered, the precipitation being effected with a mixture of lime and alumino-ferric.

We inspected this plant as working at Dye Works, No. 18, where low class woollen goods are dyed and finished. Dye liquor alone is dealt with in the plant at this mill, the total volume being about 45,000 gallons per working day.

The apparatus consists of four cylindrical towers, each 30 feet high, having diameters of 3, 8, 7, and 7 feet, respectively.

The waste liquor is pumped from a collecting sump to the top of the apparatus, where the chemicals are added automatically. It then passes down the smallest or mixing tower and into the largest tower, up which it rises at the rate of about 2 inches a minute.

From the top of this (8 feet diameter) tower the partially clarified liquor is carried down to the bottom of the two smaller (7 feet diameter) towers in two separate pipes, half of it then passing up one tower and half up the other.

At the top of each of the smaller towers there is a layer of wood shavings, through which the liquid passes before leaving the apparatus.

The total capacity of all the tanks together is 25,000 gallons.

The sludge is discharged automatically from the bottom of each tower. It is drained on sludge filters composed of broken stone covered with clinker, and is tipped when sufficiently dry to be carted.

There are six sludge filters, each 9 feet by 8 feet. They are protected with a light roof.

It may be useful to add that the whole apparatus, including the sludge filters, occupies an area of only 165 square yards.

The representatives of the West Riding of Yorkshire Mill Owners' and Occupiers' Association were kind enough to give us the following figures of analysis relating to the crude dye liquor and the final effluent at this mill. The figures refer to average samples taken every hour over a working day.

DYE WORKS, No. 18.

	Parts per 100,000.			
	Dye liquors before treatment.		Final effluent from apparatus.	
Appearance of sample.	Greenish.		Straw coloured.	
Solids in suspension	14·4		1·6	
Loss on ignition		10·0		0·40
Ash		4·4		1·20
Solids in solution	227·6		198·4	
Loss on ignition		29·0		19·6
Ash		198·6		178·8
Alkalinity (as H_2SO_4)			7·3	
Acidity (as H_2SO_4)	2·50			
Hardness (total)	74·0		80·0	
Fatty matter (extracted by ether)	0·7		4·0	

The following analytical figures, taken from tables handed in by Dr. H. Maclean Wilson, also relate to the same mill :—

DYE WORKS No. 18.

Sample.	Parts per 100,000.			
	Crude liquor before treatment.	Effluent from 8-feet tower.	Final effluent.	Final effluent.
	Average samples taken from 10.15 a.m. to 4 p.m. on September 25th, 1908.			Average of eight chance samples.
Ammoniacal nitrogen	0·81	0·85	1·00	0·56 *
Albuminoid nitrogen (Wanklyn)	0·39	0·25	0·28	0·27 *
Organic nitrogen (Kjeldahl)	0·97	0·69	0·66	
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F.	5·30	2·55	2·55	2·94
Alkalinity (as Na_2CO_3)	Nil.	Trace.	Trace.	4·9 (app.)
Acidity (as H_2SO_4)	Nil.			Trace in one sample.
Hardness :—				
Temporary	43·0	5·5	6·4	1·6
Permanent	59·0	76·6	78·1	57·7
Total	102·0	82·1	84·5	59·3
Solids in suspension (dried at 100° C.)	7·68 (ash 2·52)	2·20 (ash 1·68)	2·28 (ash 1·20)	2·60* (ash 1·83)*
Solids in solution (dried at 100° C.)	238·80 (ash 202·80)	265·60 (ash 229·00)	270·20 (ash 234·60)	230·1 (ash 204·3)
Total solids	246·48	267·80	272·48	231·42

* Four Samples (0·5 to 3·8).

It will be seen that the two sets of figures in the above tables are in fair agreement.

They shew that the process removes the greater part of the suspended matter, without affecting the permanent hardness of the liquor to any marked extent. The temporary hardness is much reduced, according to Dr. Wilson's figures.

The final effluent is mixed with well water in the proportion of about 1 to 4, the mixture being used for dyeing, condensing, and flushing closets.

We were informed by the representatives of the West Riding Mill Owners' Association that they considered that the cost of the process would be excessive at any mill where it was not possible to use the effluent water again.

The following analyses relating to the sludge from the "Waite" apparatus is taken from a table handed in by Dr. H. Maclean Wilson.

Sample collected.	Parts per 100.		
	Sludge from sludge filters.		
	August, 1904.	September, 1904.	September, 1908.
Calculated on the moist sludge.			
Moisture	82·30	80·51	93·51
Organic and volatile matter	8·64	12·02	2·56
Ash	9·06	7·47	3·93
	100·00	100·00	100·00
Calculated on the dry solids.			
Organic and volatile matter	48·81	61·67	39·45
Ash	51·19	38·33	60·55
	100·00	100·00	100·00
Nitrogen (Kjeldahl)	—	—	0·83
Fat (after acidification)	14·24	26·63	—

(*b*) Settlement without the Aid of Chemicals.

In particular cases, notably those where the dye liquors are derived from cotton dyeing, it is possible to remove the greater part of the suspended matter from these liquors by the use of settling tanks alone, or settling tanks with straining filters, without the preliminary addition of chemicals.

The following analytical figures which have been supplied to us by Dr. H. Maclean Wilson relate to cases of this kind.

SETTLING TANKS ALONE.

Sample collected.	Parts per 100,000.		
	Tank effluent.		
	October 21st, 1910.	February 28th, 1910.	October 25th, 1910.
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F	3·84	4·56	0·86
Alkalinity (as Na_2CO_3)	Slight.		10·6
Acidity (as H_2SO_4)		Very slight.	
Hardness :—			
Temporary	Nil.	Nil.	Nil.
Permanent	14·9	18·6	26·9
Total	14·9	18·6	26·9
Solids in suspension (dried at 100° C.)	3·0 (ash 0·2)	3·2 (ash 0·3)	1·4 (ash 0·65)
Solids in solution (dried at 100° C.)	39·0 (ash 27·4)	39·9 (ash 28·2)	64·5 (ash 48·5)
Total solids	42·0	43·1	65·9
Physical characteristics	Opalescent liquid with brownish tint, and containing some dark brown suspended matter.	Opalescent liquid with yellow-brown tint, and containing a small quantity of brown suspended matter.	Clear colourless liquid, containing a small quantity of reddish-brown suspended matter.

SETTLEMENT AND FILTRATION.

Sample collected.	Parts per 100,000. Filter effluent. July 28th, 1910.	Parts per 100,000. Filter effluent. August 22nd, 1910.
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F.	3·85	3·48
Alkalinity (as Na_2CO)	Slight.	Slight.
Hardness :—		
Temporary	1·5	Nil.
Permanent	6·3	6·5
Total	7·8	6·5
Solids in suspension (dried at 100° C.)	1·6 (ash 0·6)	2·3 (ash 0·4)
Solids in solution (dried at 100° C.)	102·6 (ash 91·1)	78·0 (ash 69·4)
Total solids	104·2	80·3
Physical characteristics	Clear liquid with reddish-brown tint, and containing a small quantity of brown suspended matter.	Opalescent liquid with brown tint, and containing a small quantity of brown suspended matter.

If the figures of analysis given in this section are compared with those set out under the head of Dyeing in the Cotton Trade, it will be seen that effluents derived from this process of settlement alone, or of settlement and filtration, are less pure organically and less well clarified than those derived from the precipitation processes, but that—on the other hand—they are much less "hard."

Summary as regards Dyeing in the Woollen Trade.

The analyses which have been given show that the waste from woollen dyeing, though polluting, is much less so than many other kinds of trade refuse. There appears to be little difficulty in reducing the suspended solids in this class of waste to 4 parts per 100,000, and we think, therefore, that it would be reasonable to ask for clarification to this extent.

(2) *Yarn, Piece and Blanket Scouring.*

62. A certain condition of oiliness is necessary in wool before it can be spun into yarn, and in yarn before it can be woven into cloth.

The degree of this oiliness depends to some extent upon the length of fibre of the wool which is used, more oil being required for short than for long fibre.

The condition is brought about by the addition of a saponifiable oil to the wool before it is carded.

After the weaving process the pieces of cloth, flannel or blanket, as the case may be, are first "scoured" and then "milled," or *vice versa*.

In the milling process the cloth, wet with a solution of soap, is either pommelled in stocks or squeezed in a milling machine. A soapy solution results as a waste liquor from this process, but it is only of small volume. For purposes of purification it may be considered as part of the scouring liquor.

In the process of scouring, the main object is to remove the oil added previous to the carding, and the goods dealt with generally represent the final product or one of the final products of the mill, which may be yarn, pieces of cloth, flannel, blankets, etc. The process is simply one of washing, the goods being passed through a solution of alkali (sodium carbonate or ammonia or both) and soap, and afterwards washed or rinsed in running water.

Frequently large quantities of Fuller's earth are used, especially in blanket scouring.

The waste liquors from the process may be divided into :—

(*a*) The scouring solution ; a grey brown, turbid and alkaline liquor, containing oil, soap, Fuller's earth, etc.

(*b*) The wash water ; a liquor of the same nature as the scouring solution, but gradually becoming more and more dilute as the washing proceeds.

Yarn and piece scouring liquors differ considerably in strength, and to some extent in character and composition, at every mill, but generally speaking they may be classed together as requiring similar treatment before being discharged into streams.

The scouring solution, though of relatively small volume, is of a very polluting character, mainly because of the greasy suspended matter which it contains, but also, to some extent, because of its dissolved impurities.

The first rush of the "wash" water must be classed in the same category. The last washings are only slightly polluting, but they comprise a large volume of water.

The mills which produce these scouring liquors are situated both in urban and rural districts.

There are two methods of dealing with the waste liquors from yarn or piece scouring, neither of them entirely satisfactory, but both effecting the removal of the greater part of the suspended impurities. They may be described very briefly, as follows :

Method (1).—The thick scouring solution is collected in tanks (seak tanks), where it is thoroughly mixed with an excess of acid (usually sulphuric) and then allowed to remain quiescent. The fatty acid of the emulsified soap, being liberated by the mineral acid, separates out, some of it rising to the top of the liquor as a scum, and some falling with the heavy dirt to the bottom of the tank.

The scum having been removed, the brown acid water, which is still turbid, is run off and treated with the wash water.

The greasy sludge or magma is then run on to draining filters, and finally, when sufficiently dry, pressed hot for the recovery of grease.

The mixed "acid liquor" and wash waters are precipitated with lime or alumino-ferric, or both, and then settled in tanks. In a number of cases the tank liquor is strained through filters before being discharged. Such filters have the effect of preventing the occasional discharge of very turbid effluents when tanks are improperly worked.

In our opinion, the objection to this process is that the addition first of acid and then of lime has the effect of increasing very considerably the permanent "hardness" of the effluent.

On the other hand, the recovery of the grease or oil is sometimes, though not always, profitable to the manufacturer, this depending upon the amount and kind of oil added in the first instance.

As an example of this method of treatment of piece scouring solution without wash water, we may cite some figures which have been given to us by Dr. H. Maclean Wilson, of the West Riding Rivers Board.

Mill No. 19.

These figures relate to a mill in the West Riding of Yorksihre, where the business of "finishing" woollen and worsted goods is carried on. The purification plant was designed by Messrs. Thomas Waite & Co., Bradford.

The scouring solution, amounting to about 20,000 gallons per day of ten hours, is collected in a sump of 4,500 gallons capacity, and thence pumped into the "seak" tanks, of which there are three, each having a capacity of 10,000 gallons.

To the contents of each tank, when full, are added some ten or eleven gallons of vitriol, the mixture being subsequently stirred by the injection of air and steam.

After the separation of the fatty acid, the acid liquor is run to a neutralising tank (capacity 3,500 gallons), milk of lime being added at the same time. About 30 lbs. of quick lime are added to the acid water from each "seak" tank.

The neutralised and partially settled liquor is conveyed from the neutralising tank to a circular percolating filter, over which it is distributed by means of a revolving sprinkler. The filter is 30 feet in diameter and 4 feet deep. It is composed of broken stones and ashes, varying from ¼ inch diameter at the top to 2 inches diameter at the bottom.

The sludge from the seak tanks is treated for the recovery of grease in the usual way.

The sludge from the neutralising tank is run on to a draining filter composed of cinders.

ANALYSES RELATING TO MILL NO. 19.

	Parts per 100,000.			
	Crude scouring liquor. One sample.	"Seak" tank liquor. Average of three samples.	"Neutralising" tank liquor. Average of four samples.	Filter effluent. Average of seven samples.
Ammoniacal nitrogen	0·32	0·63	0·55*	0·48†
Albuminoid nitrogen (Wanklyn)	2·33	1·09	0·94*	0·26†
Organic nitrogen (Kjeldahl)	4·50	2·05	2·11*	0·54†
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F.	31·77	13·07	9·93	1·02
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F. (after paper filtration)	18·63	2·87	2·53	0·67‡
Alkalinity (as Na_2CO_3)	103·9			
Acidity (as H_2SO_4)		83·3	59·94	14·55
Hardness:—				
Temporary		19·13	13·3	4·8
Permanent		58·80	58·27	43·8
Total		77·93	71·57	48·6
Solids in suspension (dried at 100° C.)	99·2 (ash 9·55)	72·57 (ash 1·03)	54·80 (ash 1·39)	1·47§ (ash 0·44)
Solids in solution (dried at 100° C.)	220·4 (ash 120·4)	270·70 (ash 198·6)	261·67 (ash 199·7)	239·08 (ash 210·9)
Total solids	319·6	343·35	316·47	240·55
Fat	139·2	63·3	60·9*	

* Three samples. † Five samples. ‡ Six samples. § (0·24 to 6·08.)

The foregoing samples are not strictly comparable and this should be borne in mind in reading the figures. They serve to shew the turbid greasy nature of the crude scouring solution, and the marked purifying effect of the treatment.

There is probably little oxidation of dissolved impurities by the filter, but the volume of liquor treated is large (192 gallons per cube yard per 24 hours) and the rate of filtration, during the 10 hours of actual working, very high, viz., a rate of 460 gallons per cube yard per 24 hours.

Dr. Wilson gives the following analytical figures for the sludges from (*a*) the seak tank; and (*b*) the neutralising tank:—

	Parts per cent.	
	Magma or Sludge from "Seak" Tanks.	Sludge from "Neutralizing" tank.
Sample collected.	January 5th, 1909.	January 5th, 1909.
Calculated on the moist sludge.		
Moisture	64·50	69·75
Organic and volatile matter	34·30	17·23
Ash	1·20	13·02
	100·00	100·00
Calculated on the dry solids.		
Organic and volatile matter	96·70	57·00
Ash	3·30	43·00
	100·00	100·00
Nitrogen (Kjeldahl)	3·14	0·69
Total fatty matter	78·60	40·00

MILL NO. 20.

Another example of the same method of treatment, as carried out at Mill No. 20. in the Mersey and Irwell district, may be cited.

At this mill the trade process is that of "finishing" heavy woollen goods. The total volume of waste liquor, which comprises the piece scouring solution and the wash water, amounts to about 50,000 gallons per working day.

The thicker scouring suds are treated separately for the recovery of grease in two sap or seak tanks, which have a total capacity of 6,600 gallons. Sulphuric acid is used in this process, about 6 or 7 gallons being mixed with the contents of each tank.

The clarified acid liquor from the seak tanks is mixed with the wash water, the mixture precipitated with alumino-ferric and then settled in tanks. The liquor first passes through a horizontal circular tank made from two old boilers and then into one or other of three rectangular tanks, which are used in parallel and which have a total capacity of 70,000 gallons.

The tank liquor is finally strained through filters before being discharged.

The filters have a total area of 200 square yards. They are composed of graded cinders, 18 inches in depth, covered with a layer of sawdust, 4 to 6 inches deep, and above that with a layer of fine sand.

The magma or sap from the seak tanks is drained on a sludge filter composed of fine cinders and having an area of 18 square yards.

The sludge from the settling tanks is drained on similar sludge filters (total area 109 square yards), and when sufficiently dry is carted to a tip.

The following figures of analysis, relating to samples drawn at this mill on July 25th, 1910, have been supplied to us by Mr. Frank Scudder.

MILL No. 20.

	Samples collected on July 25th, 1910. Chemical results expressed in parts per 100,000.	
	Before treatment.	After treatment.
Free and saline ammonia	11·20	1·34
Albuminoid ammonia	3·25	0·07
Oxygen absorbed (from N/80 permanganate) :—		
(*a*) 3 minutes' test at 60° F.	9·50	0·19
(*b*) 4 hours' test at 60° F.	48·60	0·78
(*c*) After 4 days' incubation at 75·5° F. in sealed pipette :—		
(*a*) 3 minutes' test	15·70	0·20
(*b*) 4 hours' test	40·00	0·78
Dissolved oxygen (1 part + 3 parts tap-water) incubated at 75° F. :—		
Oxygen consumed :—		
(*a*) In 24 hours	3·53	0·88
(*b*) In 48 hours	—	2·05
Action of HCl on effluent at 100° C. :—		
Insoluble in acid :—		
Mineral	165·0	None.
Volatile	300·4	None.
Total	465·4	None.
Fatty matter :—		
Ether extract after acidification	209.4	1·74
Suspended solids :—		
Mineral	76·4	Trace of fatty matter in granules, too small to estimate.
Volatile	24·6	
Total	101·0	
Composition of mineral suspended solids :—		
(*a*) Insoluble in HCl (SiO_2)	61.24	—
(*b*) Iron and alumina (Fe_2O_3, Al_2O_3)	9·50*	—
(*c*) Lime as $CaCO_3$	2·86	—
(*d*) Magnesia (MgO)	Trace.	
Soluble solids :—		
Mineral	233·44	75·74
Volatile	307·05	10·50
Total	540·50	85·24
Chlorides (as Cl)	14·00	4·35
Sulphates (as SO_3)	11·58	42·14
Insoluble in HCl (SiO_2)	85·71	1·24
Iron and alumina (Fe_2O_3, Al_2O_3)	44·00*	1·74†
Lime (CaO)	15·94	7·10
Magnesia (MgO)	Trace.	6·10
Alkalinity :—		
(*a*) Free—sulphuric acid (H_2SO_4) required to neutralize (*Phenol-phthalein*)	None.	None.
(*b*) Total—sulphuric acid (H_2SO_4) required to neutralize (*Litmus* boiling)	68·6	Neutral
Transparency :—		
Millimetres depth seen through	4	Over 570
Remarks	White turbid liquid with grey sediment. Smell of wool.	Clear and colourless, with one or two granules of sediment of a fatty nature. Faint smell of wool.

* More Al_2O_3 than Fe_2O_3.

† A Mixture of Fe_2O_3 and Al_2O_3.

Treatment of Scouring Liquors in "Seak" Tanks.—As showing the kind of effluent produced by the seak tank process alone, we may refer to some analyses handed in by the representatives of the West Riding of Yorkshire Mill Owners' and Occupiers' Association.

In each case the crude liquor dealt with is derived from worsted piece scouring.

The figures refer to average samples taken throughout a working day.

	Parts per 100,000.			
	Mill No. 21.		Mill No. 22.	
	Crude scouring liquor.	Effluent from "seak" tanks.	Crude scouring liquor.	Effluent from "seak" tanks.
Solids in suspension	135·0	48·0	207·0	4·0
Loss on ignition	75·0	26·0	167·0	2·8
Ash	60·0	22·0	40·0	1·2
Solids in solution	312·0	310·0	137·0	220·0
Loss on ignition	136·0	52·0	70·0	127·0
Ash	176·0	258·0	67·0	93·0
Alkalinity (as H_2SO_4)	29.0		41·0	
Acidity (as H_2SO_4)		130·0		100·0
Total hardness (as $CaCO_3$)		21·0	Nil.	21·0
Fatty matter extracted by ether	179·0	None.		Trace.
Gallons of scouring liquor dealt with per day	25,000		40,000	
Total capacity of seak tanks, in gallons	20,000		60,000	

In both of these cases the effluent is discharged into a stream without further treatment.

It will be seen that at Mill No. 22 (where the seak tank capacity is large in proportion to the quantity of waste liquor), only 4·0 parts per 100,000 of suspended matter remain in the effluent, while at Mill No. 21 (where the seak tank capacity is small), the effluent contains 48·0 parts.

Although the effluents themselves are not very hard, the excess of sulphuric acid which they contain must considerably increase the permanent hardness of the water of the streams into which they are discharged, by reason of its action upon the carbonate of lime and magnesia in the water and upon any limestone, etc., in the bed of the stream.

As has been pointed out, artificial neutralization with lime produces the same undesirable effect.

Method 2.—The scouring solution and the wash waters are mixed together, precipitated, settled and filtered.

As an example of this method of treatment we may refer to Mill No. 23 in the Irwell watershed, where the processes of flannel finishing and woollen dyeing are carried on. A detailed account of this process is given in the Appendix (No. 2).

The waste liquids from the finishing department, *i.e.*, the scouring solution and the wash water from the scouring, are mixed together and treated independently of the dye liquor and dye wash waters.

The total volume of waste from the finishing department is approximately 150,000 gallons per working day. This liquor is first screened through a fine copper sieve, for the purpose of removing the "flocks," after which it passes to a pump well. From the pump well it is lifted by two pumps to a box, where it falls on a water wheel which works a lime mixer.

First, lime (about 3 cwts. per working day) and then partially oxidized ferrous sulphate* (about 1·2 cwts. per day) are added, and the mixture then flows into three main settling tanks which have a total capacity of 108,000 gallons.

The partially clarified liquor from these tanks then passes into two additional tanks, which have a total capacity of 55,000 gallons. The tank liquor is finally strained through two filters, composed of fine clinker two feet deep and having a total capacity of 36 cube yards, before being discharged into the stream.

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* We understand that unoxidized ferrous sulphate is now (1914) used and that the dye house and mill liquors are now treated together.

The sludge from the three main settling tanks is treated with vitriol, heated by means of steam, and finally pressed in a large filter press for the recovery of grease. The grease thus recovered is refined and made into a soap which is used in the works.

The acid liquor which results from the treatment of the greasy sludge with vitriol is used as a supplementary precipitant for the crude liquor.

The spent dye liquor and dye rinsing water, which together amount to about 100,000 gallons per working day of 10 hours, are first settled in tanks and then strained through shallow filters composed of clinker resting on a false bottom of perforated boarding.

There are five tanks, each having a capacity of 5,600 gallons, and four filters. The depth of the filtering material varies from 9 inches to 1 foot, and the total filter capacity is about 42 cubic yards.

The following analytical figures will give a good idea of the average strength of the crude liquors treated and the effluents derived from them. They were obtained from hourly samples taken on four working days in February and March, 1911, and from one chance sample taken in January, 1914.

MILL NO. 23.

Waste liquor from :—	Parts per 100,000.					
	Piece scouring and carbonizing.		Dyeing.		Final Effluent from Piece scouring. Chance sample. Drawn Monday, January 12th, 1914, Analysed January 14th.	
	Crude liquor. Average of 4 sets of samples drawn hourly on the following days :— February 23rd and 28th, and March 3rd and 7th, 1911.	Final effluent. Average of 3 similar sets of samples drawn February 23rd and March 3rd and 7th, 1911.	Crude dye liquor. Average of 3 similar sets of samples drawn February 23rd and March 3rd and 7th, 1911.	Final effluent. Average of 3 similar sets of samples drawn February 23rd and March 3rd and 7th, 1911.	Original Sample.	After filtration through paper.
Ammoniacal nitrogen - - -	0·95	0·29	0·15	0·11	0·09	
Albuminoid nitrogen - - -	3·55	0·59	0·32	0·20	0·20	
Total organic nitrogen - - -	—	—	—	—	0·48	
Nitrous nitrogen - - - -	—	—	—	—	0·0	
Nitric nitrogen - - - -	0·29	—	0·14	0·11	0·17	
Total nitrogen (Kjeldahl) - -	6·19	1·60	1·05	0·51	0·66	
Oxygen absorbed from N/8 permanganate at 27° C. at once -	9·55	0·68	0·94	0·78	0·51	
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	51·5	4·80	4·34	3·38	3.40	2·34
Incubator test (by smell) - -	—	All passed.	All passed.	All passed.	Failed (H_2S)	
Total hardness - - - -	39·5	40·8	6·71	8·36	36·3	
Permanent hardness - - -	33·2	39·1	5·19	7·26	34.4	
Dissolved oxygen taken up at 18°C. in 48 hours - - - -	25·6	2·44	3·03	2·67	3·23	
Dissolved oxygen taken up at 18°C. in 5 days - - -	59·5	6·74	6·50	4·50	7·04	6·38
Total solids - - - -	285·0	128·9	61·7	53·8		
Solids in solution - - -	169·5	125·9	50·9	47·4		
Solids in suspension - - -	115·5 { 107·2V 8·3N	3·0 { 2·1V. 0·9N.	10·8 { 7·2V. 3·6N.	6·4 { 4·8V. 1·6N.	5·3 { 3·9V. 1·4N.	
Grease (*i.e.*, volatile matter in ether extract) - - - -	78·2	1·5	2·9	3·9		
Total Alkalinity (Me.O.), as H_2SO_4					7·9	(no caustic alkalinity)

The analyses of the spent dye liquor and of the effluent obtained from it are given here for the purpose of bringing out two points, namely :—

(1) That the spent liquor and washings from a dye-house are very much weaker than the liquors from piece scouring, and—

(2) That continuous flow settlement in tanks without the use of chemicals has only a small purifying effect upon such dilute dye liquors.

The figures relating to the treatment of the piece scouring liquor show that very good clarification can be effected on this liquor by careful precipitation with lime and partially oxidized copperas, and that nearly all the greasy matter is removed at the same time. Taking the average samples, the actual percentage purification as regards suspended solids in this case is 97·4, only 3.0 parts of suspended matter remaining in the effluent. The effluent was rather "hard," but it took up only 6·74 parts of dissolved oxygen in 5 days and was non-putrescible.

A sample of the sludge, as pumped out of the dye liquor settling tanks, was drawn on March 2nd, 1911, and analysed on March 17th, after siphoning some water from it. It contained:—

Moisture	92·4	per cent.
Dry matter	7·6	,,
	100·0	

The dry matter gave:—

Volatile on ignition	64·9	per cent.	Containing 3·53 parts nitrogen. ,, 29·4 ,, fatty matter.
Non-volatile	35·1	,,	
	100·0	,,	
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	27·9	,,	

This sludge was black and homogeneous, with a slightly unpleasant smell, but it withstood incubation. It will be noted that it was rich in fatty matter and also comparatively rich in nitrogen compounds.

Scouring with Fuller's Earth.—In some branches of the woollen and worsted finishing trade, more especially in blanket finishing, a dilute solution of alkali, usually ammonia, is used in conjunction with Fuller's earth for the scouring process, in place of a strong solution of sodium carbonate.

Where much Fuller's earth is used, the recovery of grease by treatment with acid in seak tanks is said to be unprofitable.

Direct precipitation followed by settlement, *i.e.*, Method (2), may, however, be applied in these cases also with fairly satisfactory results, and in support of this statement we may refer to the evidence given by Dr. H. Maclean Wilson relative to Mill No. 24 in the West Riding of Yorkshire where rugs and blankets are made.

In this case the goods are dyed as well as scoured, but as the dye liquor is discharged into a sewer, no account need be taken of it here.

Wool and shoddy are the raw materials used at the mill in question. They are oiled, spun into yarn, dyed and woven.

The woven goods are scoured with Fuller's earth, to remove grease, etc., some 2 tons of Fuller's earth being used per week.

The volume of waste liquor produced in the scouring process is about 25,000 gallons per day of 10 hours. It is exceptionally dirty, owing to the fact that some unscoured wool is used in the mill.

The waste liquor first flows to a screening chamber, where alumino-ferric is added, and then to an installation of six settling tanks, used in series on the continuous flow plan. The capacity of each tank is 10,000 gallons.

The tank liquor is then streamed through filters, of which there are two, each 30 feet by 15 feet and 4 feet deep. The filtering material consists of broken stone covered with screened clinker, and varies in grade from 2 inches diameter at the bottom to ½ inch diameter at the top.

The sludge from the tanks is drained on three filters, each 20 feet by 17 feet and 18 inches deep, constructed in the same way and of the same materials as the larger filters. The drained sludge is tipped on an adjoining field.

MILL No. 24.

	Parts per 100,000.		
	Crude scouring liquor. Average of two chance samples.	Tank liquor. Average of two chance samples.	Filter effluent. Average of six chance samples.
Ammoniacal nitrogen	1·16	0·70	0·67*
Albuminoid nitrogen (Wanklyn)	4·96	0·12	0·10*
Organic nitrogen (Kjeldahl)	9·96	0·42	0·37†
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F.	25·64	1·27	0·77
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F. after paper filtration	2·09	1·18	0·74
Alkalinity (as Na_2CO_3)			
Acidity (as H_2SO_4)			
Hardness :—			
Temporary	36·45	1·75	12·68
Permanent	49·65	30·85	49·39
Total	86·10	32·60	62·07
Solids in suspension (dried at 100° C.)	802·7 (ash 462·05)	1·34 (ash 1·21)	2·28* (0·48 to 5·60) (ash 1·49)
Solids in solution (dried at 100° C.)	103·4 (ash 76·4)	64·20 (ash 50·2)	95·4 (ash 75·1)
Total solids	906·1	65·5	97·3

* Five samples. † Four samples.

Analytical figures relating to the precipitation sludge are given by Dr. Wilson as follows :—

	Parts per cent.	
	Sludge from sludge filter.	Air dried sludge.
Sample collected.	January 20th, 1909.	January 20th, 1909.
Calculated on moist sludge.		
Moisture	89·46	58·79
Organic and volatile matter	3·61	15·43
Ash	6·93	25·78
	100·00	100·00
Calculated on dry solids.		
Organic and volatile matter	34·30	37·45
Ash	65·70	62·55
	100·00	100·00
Nitrogen (Kjeldahl)	1·03	1·04
Total fatty matter	23·90	22·27

The following evidence may be referred to in connection with the purification of yarn, piece, and blanket scouring liquors :—

Mr. Frank Scudder, July 12th, 1898, First Report, Evidence, p. 29, *et seq.*

Dr. H. Maclean Wilson, January 26th, 1909, answer to question 27,342, *et seq.*

Messrs. Stowell and Scudder, March 26th, 1909, p. 74, section (*f*), *et seq.*

Messrs. Tod and Toyne, June 11th, 1909, answer to question 28,713, *et seq.*

Mr. Thorp Whittaker, June 16th, 1909, answer to question 29,435, reply to query No. 3.

Mr. T. J. S. Roberts, October 25th, 1909, answer to questions 29,540–54.

All these witnesses agreed as to the practicability of removing the greater part of the suspended matter from scouring liquors.

Messrs. Tod and Toyne said that in their case precipitation with lime and ferrous sulphate, followed by settlement and filtration, produced results which were satisfactory, except so far as hardness was concerned.

Summary as regards Yarn, Piece and Blanket Scouring in the Woollen Trade.

The waste liquors from yarn, piece and blanket scouring contain a good deal of dissolved organic matter as well as much greasy solid in suspension.

Clarification improves them to a great extent, but a polluting and putrescent liquor still remains.

The analytical figures relating to suspended matter in the settled and filtered effluents from these liquors vary very considerably according to the class of trade carried on, but from a general survey we conclude that reduction to 4 parts per 100,000 is practicable in most cases.

(3) *Piece and Yarn Scouring Liquor with Dye Liquor.*

63. The methods usually adopted for treating piece or yarn scouring liquor when mixed with dye liquor are the same as for piece or yarn scouring liquor alone.

Either the scouring liquor is treated in seak tanks and the resulting liquor, mixed with the dye liquor and wash water, is precipitated, settled and (sometimes) filtered ; or else the crude liquids and the wash waters are mixed together, precipitated, settled and filtered, without the recovery of grease in seak tanks.

This combination of waste liquors is very frequently met with in practice, and for this reason several examples of its treatment may be given.

Seak Tanks followed by Settlement and Filtration.—As an example of this process we may refer to Mill No. 25, in the West Riding of Yorkshire, where imitation seal skins, woollen and union piece goods, rugs, blankets and yarns are made.

The processes which give rise to waste liquors at this mill are piece and yarn scouring and dyeing. Only yarn is dyed here, ground logwood and potassium bichromate being used in the dyeing process. The spent logwood is screened out of the waste dye liquor as the latter flows to the purification plant.

The yarn and piece scouring liquors are delivered into two wooden seak tanks (capacity of each 6,000 gallons), where vitriol is added and the grease removed in the usual way.

The greasy sludge is drained for two or three days on filters composed of engine ashes covered with a layer of spent logwood, and then pressed in steam-heated presses.

The liquor from the seak tanks is mixed with the remaining liquid wastes from the mill (wash water from the yarn and piece scouring processes, spent dye liquor and dye wash water), the whole (amounting to about 15,000 gallons per day of 10 hours) then flowing to the settling tanks.

The settling tanks, of which there are two, have a total capacity of 64,000 gallons. They are used in series.

The settled liquor is finally streamed through filters composed of engine ashes, mostly from $\frac{1}{2}$ inch to 2 inches in diameter, but with a layer of very fine material $\frac{1}{8}$ inch to $\frac{1}{4}$ inch diameter on the surface. The material is 2 feet 6 inches in depth. There are two filters, with a total content of 70·8 cubic yards.

The sludge from the settling tanks is drained on filters and tipped when sufficiently dry.

The following figures relating to this mill have been obtained from tables handed in by Dr. H. Maclean Wilson :—

MILL No. 25.

Parts per 100,000.

	Water from reservoir (used for scouring).	Water from streams (used for dyeing).	Crude scouring liquor.	Crude dye liquor.	Seak tank liquor.	Mixed liquors entering settling tanks.	Mixed liquors leaving settling tanks.	Filter effluent as flowing to stream.
	One chance sample.	One chance sample.	One chance sample.	One chance sample.	Average of two chance samples.	Average of two chance samples.	Average of two chance samples.	Average of five chance samples.
Ammoniacal nitrogen - - - -	Trace.	0·018	9·63	12·99	7·42	2·92	2·25	1·91†
Albuminoid nitrogen (Wanklyn) - -	0·003	0·017	3·70	15·60	1·43	1·55	0·36	0·30†
Organic nitrogen (Kjeldahl) - -	0·023	0·080	10·81	25·82	2·94	4·61	0·75	0·55†
Oxygen absorbed from N/80 permanganate in 4 hours at 80° F. - -	0·06	0·15	28·46	101·60	9·65	17·34	2·90	1·62
Alkalinity (as Na_2CO_3) - - -	Trace.	Trace.	281·90			76·3		Trace in three out of five.
Acidity (as H_2SO_4) - - - -				Trace.	34·8		Trace.	Trace in two out of five.
Hardness :—								
Temporary - - - - -	2·40	10·80		52·5	41·25	22·7	10·15	11·07‡
Permanent - - - - -	16·40	40·70		650·5	145·25	5·7	38·95	39·17‡
Total - - - - -	18·80	51·50		703·0	186·5	28·4	49·10	50·23‡
Solids in suspension (dried at 100° C.) -	minute	4·90 (ash 2·50)	395·6 (ash 72·20)	66·5 (ash 15·0)	4·44 (ash 0·20)	133·7 (ash 47·0)	7·25 (ash 2·38)	1·88§ (ash 0·65)
Solids in solution (dried at 100° C.) -	28·80 (ash 21·0)	61·60 (ash 46·0)	440·0 (ash 362·0)	1273·2 (ash 726·8)	801·4 (ash 683·5)	175·5 (ash 145·35)	208·80 (ash 185·5)	258·58 (ash 237·5)
Total solids - - - - -	28·80	66·50	835·6	1339·7	805·84	309·2	216·05	260·46
Fat (after acidification) - - -			249·3		6·9*	76·5		

* One Sample. † Average of two Samples. ‡ Average of three Samples. § Trace—4·00.

The samples are not strictly comparable and this should be borne in mind when reviewing the figures.

It will be seen that, although the final effluent contains very much more organic impurity and dissolved matter than the water of the stream into which it is discharged, yet it is a great improvement on the mixed liquors arriving for treatment, especially as regards suspended matter. The suspended matter in the samples which go to make up the average (1·88 parts) varied from a trace to 4·0 parts per 100,000.

The degree of hardness is practically the same as that of the stream water, but the dissolved matter, which is mainly inorganic, is materially increased.

For the figures given in the next four tables of analysis, we are indebted to the West Riding Mill Owners' and Occupiers' Association:—

MILL No. 26.

	Parts per 100,000.			
Kind of sample analysed.	Crude scouring solution with dye liquor and wash waters.		Final filter effluent.	
	Mixture of samples taken every hour over a working day.		Mixture of samples taken every hour over a period of two working days.	
Appearance of sample.	Dark green, turbid liquor.		Light green.	
Solids in suspension	1562·94		14·8	
Loss on ignition		1328·43		11·7
Ash		234·51		3·1
Solids in solution	626·51		142·6	
Loss on ignition		199·12		43·4
Ash		427·39		99·2
Alkalinity (in terms of H_2SO_4)	314·95		4·9	
Hardness (total)	5·68		23·82	
Fatty matter (extracted by ether)	110·4		3·5	

MILL No. 27.

	Parts per 100,000.					
Kind of sample analysed.	Crude scouring solution.		Acid "seak" tank liquor with dye liquor and wash water.		Final filter effluent.	
	Mixture of samples taken every hour throughout a working day.		Mixture of samples taken every hour throughout a working day.		Mixture of samples taken every hour over a period of two working days.	
Appearance of sample.	Deep black.		Deep green.		Brownish green.	
Solids in suspension	360·0		50·8		7·2	
Loss on ignition		305·0		43·4		4·4
Ash		55·0		7·4		2·8
Solids in solution	479·0		270·4		160·6	
Loss on ignition		240·0		43·2		22·0
Ash		239·0		227·2		138·6
Alkalinity (in terms of H_2SO_4)	156·31		2·94		5·14	
Hardness (total)			11·7		28·57	
Fatty matter (extracted by ether)	44·5		1·85		0·25	

Mill No. 28.

Kind of sample analysed.	Parts per 100,000.			
	Crude scouring solution with dye liquor and wash waters		Final filter effluent.	
	Mixture of samples taken every hour throughout a working day.		Mixture of samples taken every hour throughout a working day.	
Appearance of sample.	Black.		Greenish yellow.	
Solids in suspension	208·0		6·6	
Loss on ignition		183·2		5·8
Ash		24·8		0·8
Solids in solution	469·2		301·4	
Loss on ignition		229·0		38·2
Ash		240·2		263·2
Alkalinity (in terms of H_2SO_4)	110·74			
Acidity (in terms of H_2SO_4)			34·3	
Hardness (total)	9·57		46·3	
Fatty matter (extracted by ether)	78·0		2·25	

In all three foregoing cases the suspended solids are largely removed by the purification process. In two of them less than 8·0 parts per 100,000 remain, but in the other, over 14·0 parts are still present in the effluent. In the last case the tank capacity is comparatively large in proportion to the volume dealt with, but the crude liquor is exceedingly turbid.

In all three instances the hardness of the liquor is increased by the treatment.

Precipitation and Settlement.—An example of the treatment of a mixture of rather dilute piece scouring liquor and dye water by precipitation and settlement may be given.

In this case no seak tanks are used and there is no recovery of grease.

It will be seen from the figures of analysis that the mixture of crude liquors is hard, but almost free from grease. The final effluent is less hard, but it contains 11 parts of suspended solids.

Mill No. 29.

Kind of sample analysed.	Parts per 100,000.			
	Crude scouring solution with dye liquor, and wash waters.		Tank liquor as discharged into the stream.	
	Mixture of samples taken every half-hour throughout a working day.		Mixture of samples taken every half-hour throughout a working day.	
Appearance of sample.	Violet-coloured liquid with black sediment.		Straw-coloured.	
Solids in suspension	40·8		11·2	
Loss on ignition		29·6		6·0
Ash		11·2		5·2
Solids in solution	226·0		128·0	
Loss on ignition		29·0		15·0
Ash		197·0		113·0
Alkalinity (in terms of H_2SO_4)	38·6		27·2	
Hardness (total)	55·0		41·0	
Fatty matter (extracted by ether)	1·8		None.	

Summary as regards Piece and Yarn Scouring with Dye Liquor in the Woollen Trade.

The remarks made with regard to yarn, piece and blanket scouring liquors apply here also.

Clarification greatly improves the mixed liquors but still leaves a polluting liquid.

Our analytical data are confined to the results handed in by Dr. Maclean Wilson and by the West Riding of Yorkshire Millowners' Association.

From the results obtained at Mill No. 25 and from the analogy between this combination of waste liquors and those from yarn, piece and blanket scouring, we should be disposed to think that reduction to 4 parts per 100,000 would not be an unreasonable requirement.

(4) *Wool Scouring, Piece or Yarn Scouring and Dye Liquors.*

64. This combination of waste liquors is usually met with in connection with the heavy fine-woollen trade, and at mills where the whole process of woollen cloth manufacture is carried through from beginning to end.

Wool scouring or wool washing consists in the washing of wool in such a way as to remove the grease and dirt with which it is naturally associated.

The process is usually carried out in three long narrow tanks or "bowls," the first two of which contain hot solutions of soap or alkali, or both, and the third water alone. Sometimes a continuous flow of clean water is passed through the third bowl.

By means of mechanical rakes the wool is slowly passed through each bowl in succession, with considerable agitation. It issues from the third bath almost free from grease, this being left, with the dirt, mainly in the first two bowls.

When the contents of the bowls become too dirty for further use they are run off and the bowls are filled with fresh solutions.

The liquor from the first two bowls is a thick greasy liquid of a brown colour. It is always strongly alkaline in reaction.

The liquor from the third bowl is of the same nature but usually much more dilute.

The following analyses, which have been supplied by Dr. H. Maclean Wilson, will give an idea of the character of wool scouring liquor. They refer to the crude suds as run off from the first and second bowls at a wool scouring mill in the West Riding of Yorkshire :—

	Parts per 100,000.	
	Crude discharge from first bath.	Crude discharge from second bath.
Oxygen absorbed from N/8 permanganate in 4 hours	419·0 (paper filtered 221·9)	167·3 (paper filtered 91·7)
Suspended solids	2489·2 (ash 213·4)	1007·2 (ash 117·6)
Soluble solids	2650·0 (ash 1737)	1108·0 (ash 602·4)
Reaction	Alkaline.	Alkaline.

Wool scouring liquor or wool suds is, therefore, excessively strong and polluting. Its treatment, when it occurs alone, is dealt with in Section 3 of this report.

When it occurs in conjunction with piece or yarn scouring liquors and dye liquors, it frequently becomes so much diluted that the mixture may be properly included here as a waste which may be greatly purified by clarification alone.

As examples of the treatment of such a combination of waste liquors from woollen mills, we may give some figures of analysis relating to two mills in the Galashiels district :—

MILL No. 30.

At this mill pure wool is manufactured into cloth, which is dyed and finished. Four wools are used, namely—Colonial, Scotch, lamb's wool, and merino.

The waste liquors produced in the course of the manufacturing process are :—

(1) Wool scouring liquor.
(2) Piece scouring liquor.
(3) Piece rinsing water.
(4) Dye water.

Of these the dilute piece rinsing water constitutes by far the largest volume. It contains some Fuller's earth, which is used in the "milling" process, but this is, to some extent, removed in a settling tank through which the piece rinsing water passes on its way to the main sump.

The spent dye water with the rinsing water from the dye house is also large in volume. Aniline dyes are used, with some "chrome" and indigo. The thick spent liquors from the indigo vats, which are almost sludges, are tipped and covered up.

The purification process at this mill may be described briefly as follows :—

The wool suds and the piece scouring liquors are run into separate seak tanks and treated with acid, for the recovery of grease in the first case and oil in the second.

The acid seak tank liquors are then run into the main sump, which also receives the other waste liquors and all the wash waters from the mill. The partially mixed liquors are pumped from the collecting sump to the precipitation tanks. There are five of these tanks, each holding 15,000 gallons, so that the total capacity is 75,000 gallons. They are constructed of cast iron.

From 9 to 12 tanks are filled per day, the average being 12. The total flow of waste liquor may thus be put at about 180,000 gallons per working day of 10 hours.

As each tank is filled, the contents are well precipitated with (milk of) lime and copperas, about 20 lbs. of each being used.

The contents of the tank are then given quiescent settlement for a period of 3 to 14 hours, after which the top water is run off to the river.

The tanks are sludged once every 3 or 4 weeks, the sludge being dried on beds of gravel and ashes. The dried sludge is carted and tipped.

The following figures relate to average samples taken at this mill in 1909 :—

Mill No. 30.

	Parts per 100,000.					
	No. 139. Wool scouring liquor. Average of four samples, taken in equal quantities. The first bowl was emptied four times in the day. As a rule only the contents of the first bowl are discharged. The contents of the other bowls are "moved up."	No. 140. Acid liquor from wool scouring liquor. Average of three samples drawn in equal quantities. (This sample does not correspond to No. 139.)	No. 141. Crude piece scouring liquor. Average of fourteen samples in equal quantities from 6.0 a.m. to 4.30 p.m. (Ammonia and soap are used in this scouring process.)	No. 142. Acid water from piece scouring liquor. Average of four samples in equal quantities drawn each time a tank was run off.	No. 143. Crude strong dye liquor. Average of ten samples in equal quantities drawn as dye vats were discharged. Mostly aniline dyes are used. There was some "chrome" water in this sample.	No. 144. Piece rinsing water. Average of thirteen equal samples drawn every half-hour from 6.30 a.m. to 3.30 p.m.
Drawn - - - - - - - -	December 1st, 1909	December 1st, 1909	December 1st, 1909	December 1st, 1909	December 1st, 1909.	December 1st, 1909
Analysed - - - - - - -	December 7th, 1909	December 7th, 1909	December 8th, 1909	December 8th, 1909	December 15th, 1909.	December 15th, 1909
Ammoniacal nitrogen - - - - -	4·68	48·72	19·76	27·43	0·60	0·82
Albuminoid nitrogen - - - - -	37·52	18·24	2·00	0·67	0·37	0·30
Total organic nitrogen - - - - -	104·66	42·80	4·42	1·37	0·70	0·67
Nitrous nitrogen - - - - - -	—	—	—	—	(?)	—
Nitric nitrogen - - - - - -	—	—	—	—	0·10	—
Total nitrogen (Kjeldahl) - - - -	109·34	91·52	24·18	28·80	1·40	1·49
Oxygen absorbed from N/8 permanganate at 27° C. at once - - - - - -	138·3	85·8	29·89	2·48	2·46	0·68
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours - - - - -	817·2	430·9	167·00	28·99	15·95	2·60
Total Hardness (as C_a CO_3) - - - -	100·3	117·0	4·45	257·0	45·2	17·4
Permanent Hardness (as C_a CO_3) - - -	22·6	90·1	1·27	203·0	17·7	3·2
Total solids - - - - - - -	4656·0 (3390 V.—1266 N.)*	4168·0 (2144 V.—2024 N.)	507·0 (465 V.—42 N.)	471·8 (279 V.—192·8 N.)	162·7 (35·3 V.—127·4 N.)	360·0 (49 V.—311 N.)
Solids in suspension - - - - -	2320·0 (1980 V.— 340 N.)	1580·0 (1160 V.— 420 N.)	156·0 (146 V.—10 N.)	65·2 (65·2 V.)	6·1 (4·8 V.— 1·3 N.)	177·0 (36 V.—141 N.)
Solids in suspension after acidification - -	2850·0 (2560 V.— 290 N.)	1480·0 (1130 V.— 350 N.)	302·0 (298 V.— 4 N.)	—	—	168·0 (18 V.—150 N.)
Fat extracted by ether and dried in vacuo -	1999·0	1180·0	329·0	—	7·6	26·8
Fat extracted by ether and dried further at 105° C. for half-an-hour - - - -	1980·0	1165·0	320·0	4·6	7·2	24·8
Non-volatile matter in this fat - - -	73·0	—	20·0	—	0·0	15·2
Fat extracted by ether, after acidification, and dried in vacuo - - - - - -	2186·0	1431·0	448·0	—	—	40·8
Fat extracted by ether, after acidification, and dried further at 105° C. for half-an-hour -	2096·0	1446·0	419·0	—	—	31·2
Non-volatile matter in this fat - - -	64·0	59·0	25·0	—	—	3·6
cidity (as H_2 SO_4) - - - - -	—	206·4 (P)†	—	70·2 (M)§	28·7 (P)	Neutral (P)
cidity after boiling - - - - -	—	31·7 (L)‡	—	—	—	—
lkalinity (as H_2SO_4) - - - - -	766 (M)§	361·5	99·4 (M)§	—	—	—
lkalinity after boiling - - - - -	—	—	—	—	—	—
issolved oxygen taken up at 18° C. in 24 hours	60·0	105·0	31·2	2·65	0·0	1·70
issolved oxygen taken up at 18° C. in 48 hours	513·0	657·0	139·8	2·70	3·8	3·90
issolved oxygen taken up at 18° C. in 5 days	1548·0 (6 days)	1698·0 (6 days)	330·6	36·6	9·1 + X	18·0
emarks - - - - - - - -	Dark brown, turbid liquor with an excessive amount of rather fine solids. Soapy, greasy smell. The Gooch filtrate from the original liquid was opalescent; the filtrate from the acidified liquor was bright.	Grey and very turbid liquor, with an excessive amount of black and grey solids. Strong, greasy, and sulphuretted hydrogen smell. Much sulphuretted hydrogen present. Filtrates, from both original and acidified liquor, were faintly opalescent.	Dark brown turbid liquor with much black suspended solids. Slight musty ammoniacal smell. The Gooch filtrate from the original liquid was very opalescent; from the acidified liquid faintly opalescent.	Brownish and slightly opalescent, with much greasy solids. Fishy and greasy smell. The filtrate from the suspended solids was brownish but quite clear.	Purple brown in colour and faintly opalescent, with an appreciable amount of fine, black suspended matter. Fusty smell.	Light brown and very turbid liquid, with a good deal of yellow-brown solid. Very slight fusty smell.

* V. = volatile on ignition, and N. = non-volatile. † P = using Phenol-phthaleïn as indicator. ‡ L = using Litmus as indicator. § M = using Methyl Orange as indicator.

The following figures relate to the mixed liquors before and after the precipitation process :—

MILL No. 30.

Parts per 100,000.	No. 145. Mixed wash liquors before final purification. This is a mixture of Nos. 140, 142, 143, 144 and some dye rinsing water. It should correspond to No. 146. Average of eighteen equal samples taken 6.30 a.m. to 7.45 p.m.	No. 146. Final effluent. Eight tanks run off on Wednesday, and five tanks on Thursday. Average of thirteen equal samples, drawn when each tank was half empty.	No. X. Final effluent. Chance sample. This represents the discharge from dye-house, mill-house, wool-scouring and magma mills.	No. Y. Final effluent as discharged. Fairly average sample.	
Drawn	December 1st, 1909.	December 1st and 2nd, 1909.	Thursday, December 8th, 1910, 3.30 p.m.	Tuesday, January 20th, 1914, between 9.30 a.m. and 3 p.m.	
Analysed	December 10th, 1909.	December 11th, 1909.	December 10th.	January 22nd.	
Ammoniacal nitrogen	3·28	1·84	2·31	0·61	After filtration through paper.
Albuminoid nitrogen	0·86	0·17	0·12	0·09	
Total organic nitrogen	1·61	0·30	0·31	0·14	
Nitrous nitrogen	—	trace (?).	0·10	0·0	
Nitric nitrogen	—	0·10	0·0	0·20	
Total nitrogen	4·86	2·24	2·72	0·95	
Oxygen absorbed from N/8 permanganate at 27° C. at once	2·94	0·48	—	0·43	
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	15·86	2·50	2·48	1·64	1·47
Incubator test (by smell)	—	Passed	? (Ammoniacal odour)	Passed	
Total hardness (as $CaCO_3$)	15·2	38·6	32·9 (Jan. 4th, 1911).	17·7	
Permanent hardness (as $CaCO_3$)	10·2	33·2	34·4 (Jan. 4th, 1911).	14·5	
Total solids	204·0 (68 V.—136 N.)	101·0 (18·4 V.—82·6 N.			
Solids in suspension	97·0 (47 V.— 50 N.)	7·9 (3·5 V.—4·4 N.)	*0·7 (0·4 V.—0·3 N.)	2·0 (0·7 V. ; 1·3 N.)	
Solids in solution	—	—	—	—	
Solids in suspension after acidification	94·0 (49 V.—45 N.)	—	—	—	
Fat extracted by ether and dried in vacuo	34·2	—	—	—	
Fat extracted by ether and dried further at 105° C. for ½ hour	32·2	—	—	—	
Non-volatile matter in this fat	0·0	—	—	—	
Fat extracted by ether, after acidification, and dried in vacuo	46·0	3·8	—	—	
Ditto ditto dried further at 105° C. for ½ hour	45·7	3·2	—	—	
Non-volatile matter in this fat	5·3	0·2	—	—	
Acidity as H_2SO_4	6·4 (P)	—	—	—	
Acidity after boiling	—	—	—	—	
Alkalinity, as H_2SO_4	15·0 (M)	15·0 (M)	—	†11·8	
Alkalinity after boiling	—	2·6 (P)	—	5·3 (P.)	
Dissolved oxygen taken up at 18° C. in 24 hours	11·3	0·22	—	—	
Dissolved oxygen taken up at 18° C. in 48 hours	—	—	0·59	2·35	
Dissolved oxygen taken up at 18° C. in 5 days	31·0	2·91	2·77	5·72	5·02
Remarks	Dark brown-grey turbid liquid, with much fine suspended matter and slight fishy smell. The Gooch filtrate from the original sample was somewhat opalescent; that from the acidified sample was bright and clear.	Bright and clear, with considerable white flocculent suspended matter. Very slight fusty smell. The Gooch filtrate was sparkling.	Almost clear, with slight pink tinge. A little froth on shaking. Slight fatty odour. The sample still contained 0·47 part of dissolved oxygen when analysed.	This sample was brownish tinted and opalescent, with a little fine suspended matter and a slight soapy smell.	

* There was a slight further deposit of 3 to 4 parts on keeping sample, almost entirely mineral matter (probably carbonate of lime). † Of this, 5·3 was caustic alkalinity.

The figures relating to these samples (145 and 146) are highly instructive. They shew clearly the strong purifying effect of chemical precipitation and settlement when properly carried out. Notwithstanding the very foul and greasy nature of some of the crude waste liquors, the final effluent is non-putrescible and takes up less than 3 parts of dissolved oxygen in 5 days—a figure which represents 94 per cent. purification on the crude mixture. When the effluent was drawn, it was faintly opalescent but otherwise clear. When it was analysed, 10 days later, a considerable quantity (7·9 parts per 100,000) of suspended matter had settled out. The later samples, Nos. X and Y, were similar in character to No. 146.

The effluent flows into a tributary of the Tweed, where it is so largely diluted that no trace of it is visible at ordinary times.

MILL No. 31.

At this mill wool is manufactured into cloth and the cloth is dyed.

Four waste liquors are produced, namely, wool scouring liquor, piece scouring liquor, spent dye liquor and dye rinsing water, but as the piece scouring liquor is almost all used for wool scouring, there is usually only a small quantity of it.

The mixture of wool suds and piece scouring liquor is screened and run into a receiving tank (capacity 3,800 gallons), where a small quantity of waste acid is added and where a good deal of heavy mineral matter settles. This tank is sludged every 3 or 4 weeks, the sludge being dried and finally spread over land.

From this receiving tank the liquor flows over a cill into two larger tanks (total capacity 10,000 gallons), whence, after further settlement, it is pumped out for treatment in the precipitation tanks with the dye water.

The dye water goes through a similar preliminary treatment, first passing through two tanks (total capacity 20,000 gallons), and then being pumped to the precipitation tanks.

There are 3 precipitation tanks, each holding about 10,000 gallons. In these tanks the wool-scouring liquor and the dye liquor are mixed together, usually in the proportion of about 1 of wool-scouring liquor to 2½ of dye liquor; slaked lime (120 lbs.) is added, and then, in order to insure complete mixture, air is injected into the bottom of the tank.

After a period of quiescence, which varies from 4 to 12 hours, the top liquor is drawn off and the sludge run into drying pits underneath the tanks. When the sludge is dry it is dug out, mixed with wool rubbish, and tipped.

The precipitation liquor is now mixed with the dilute dye rinsing water, and the mixture is first settled in a tank (capacity 7,500 gallons), and afterwards strained through a filter (20 cubic yards content), composed of ashes, before flowing into the river Gala, a tributary of the Tweed.

Samples of the crude wool scouring liquor and of the crude dye water from this mill gave the following figures:—

MILL No. 31.

Parts per 100,000.	No. 147. Crude wool scouring liquor, from the scouring of unlimed wool and fleeces. Average of six samples, taken in proportion to flow each time the scouring bowls were run off.	No. 148. Crude dye water. Average of three samples, taken in equal quantities each time the dye vats were run off. Aniline colours used here, and a little logwood.
Drawn - - - - - - -	December 1st and 2nd, 1909	December 1st and 2nd, 1909
Analysed - - - - - - -	December 21st, 1909	December 21st, 1909.
Ammoniacal nitrogen - - - - -	5·16	0·57
Albuminoid nitrogen - - - - -	10·00	0·78
Total organic nitrogen - - - - -	20·31	2·26
Nitrous nitrogen - - - - - -	—	0·31
Nitric nitrogen - - - - - -	—	
Total nitrogen (Kjeldahl) - - - -	25·47	2·83
Oxygen absorbed from N/8 permanganate at 27° C. at once - - - - - -	47·9	3·08
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours - - - - -	277·0	15·04
Chlorine - - - - - - -	—	—
Total hardness (as $CaCO_3$) - - - -	8·1	25·7
Permanent hardness (as $CaCO_3$) - - -	6·8	9·2
Total solids - - - - - - -	1306·0 (840 V.—466 N.)	177·2 (64·4 V.—112·8 N.)
Solids in suspension - - - - - -	460·0 (300 V.—160 N.)	4·2 (3·8 V.— 0·4 N.)
Solids in suspension, after acidification - -	300·0 (300 V.)	10·6 (9·9 V.— 0·7 N.)
Fat extracted by ether and dried in vacuo -	377·0	—
Fat extracted by ether and dried further at 105° C. for ½ hour - - - - - -	366·0	—
Non-volatile matter in this fat - - -	44·0	—
Fat extracted by ether, after acidification, and dried in vacuo - - - - - -	503·0	19·2
Fat extracted by ether, after acidification, and dried further at 105° C. for half-an-hour -	496·0	15·0
Non-volatile matter in this fat - - - -	22·0	3·2
Acidity as H_2SO_4 - - - - - -	—	Very slightly acid, evidently from carbonic acid.
Acidity after boiling - - - - -	—	—
Alkalinity as H_2SO_4 (Feb. 10th, 1910) - -	269·4 (Methyl-orange)	—
Alkalinity after boiling (Feb. 10th, 1910) - -	39·2 (Phenol-phthaleïn)	—
Dissolved oxygen taken up at 18° C. in 24 hours	51·8	0·85
Dissolved oxygen taken up at 18° C. in 48 hours	323·4	5·4
Dissolved oxygen taken up at 18° C. in 5 days -	703·0 (7 days)	20·1 (7 days).
Remarks - - - - - - -	Dark grey-brown liquor, with much greyish-brown suspended matter. Greasy smell.	Brown black in colour, with a little black suspended matter. Fusty smell.

The following analyses will give a general idea of the quality of the precipitation liquor and final effluent produced at this mill.

MILL No. 31.

	No. 149. Mixed scour and dye water, after precipitation and settlement. Average of three samples drawn in equal quantities after each tank was run off.	No. 150. Final effluent. Average of twelve samples taken every hour in equal quantities.
Parts per 100,000.		
Drawn	December 1st and 2nd, 1909.	December 1st and 2nd, 1909.
Analysed	December 15th, 1909.	December 21st, 1909.
Ammoniacal nitrogen	0·94	0·57
Albuminoid nitrogen	0·47	0·35
Total organic nitrogen	1·13	1·05
Nitrous nitrogen	0·0	0·12 approx.
Nitric nitrogen	0·20	0·24
Total nitrogen	2·27	1·62
Oxygen absorbed from N/8 permanganate at 27° C. at once	1·88	1·28
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	5·95	3·93
Incubator test (by smell)	Passed (sweet : fusty)	Passed (slight earthy odour)
Total hardness (as $CaCO_3$)	119·4	50·2
Permanent hardness (as $CaCO_3$)	50·2	37·9
Total solids	262·2 (37·8 V.—224·4 N.)	149·6 (49·6 V.—100·0 N.)
Solids in suspension	6·6 (0·2 V.— 6·4 N.)	10·0 (1·8 V.— 8·2 N.)
Solids in suspension, after acidification	11·7 (2·1 V.— 9·6 N.)	3·2 (2·3 V.— 0·9 N.)
Fat extracted by ether and dried in vacuo	—	2.4
Fat extracted by ether and dried further at 105° C. for ½ hour	—	0.4
Non-volatile matter in this fat	—	0.0
Fat extracted by ether, after acidification, and dried in vacuo	8.0	5 3
Fat extracted by ether, after acidification, and dried further at 105° C. for ½ hour	8.0	4.9
Non-volatile matter in this fat	1.6	2.1
Acidity (as H_2SO_4)	—	—
Acidity after boiling	—	—
Alkalinity (as H_2SO_4)	172·8 (M); 156·4 (P)	59·6 (P)
Dissolved oxygen taken up at 65° C. in 24 hours	0·98	1·24
Dissolved oxygen taken up at 65° C. in 48 hours	1·44	2·11
Dissolved oxygen taken up at 65° C. in 5 days	9·44	9·56
Remarks	Yellowish-green and slightly opalescent, with some whitish suspended matter and a good deal of lime. Slight fusty, greasy smell.	Greenish-yellow and opalescent, with considerable whitish suspended matter (probably carbonate of lime for the most part). Slight greasy smell.

It will be seen that the complicated process of purification adopted in this case clarifies the waste liquor very considerably, but that the effluent is still distinctly greasy and capable of taking up over 9 parts of dissolved oxygen, even though it is non-putrescible on incubation for five days.

The method of working has also the disadvantage of wasting the whole of the grease and oil.

The following figures relate to the greasy sludge which results from the lime precipitation at this mill. The figures are percentages of the sludge, as drawn.

Mill No. 31.

	No. 151. Lime precipitation sludge from the treatment of the wool scouring and dye liquors with lime. This sample had been draining on a lagoon for some days.
Sample drawn	December 2nd, 1909.
Sample analysed	January 17th and February 23rd, 1910.
	Per cent. by weight.
Moisture	70·59
Dry matter	29·41 = 100·0
Nitrogen	0·24
Fat extracted by ether and dried in Vacuo	7·20
Fat extracted by ether and dried further for half an hour at 105° C.	7·05
Non-volatile matter in this fat	1·14
Siliceous matter, insoluble in hydrochloric acid, ignited	3·34
Soluble in hydrochloric acid :—	
Sesquioxide of chromium (Cr_2O_3)	0·14*
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$)	2·00
Lime (CaO)	6·0†
Magnesia (MgO)	Not estimated.

* The actual compound of chromium present in this sludge was not determined.
† Probably containing a little magnesia.

About one-fifth of the dry substance of this sludge is thus fatty matter, and another fifth is lime salts (no doubt sulphate and carbonate).

In our opinion, it would certainly be profitable to recover the grease from this sludge.

Some analytical figures which have been supplied by the West Riding of Yorkshire Mill Owners' Association may also be given here.

They relate to a mill in Yorkshire where wool is manufactured into cloth, dyed, and finished.

Some 33,000 gallons of wool-scouring liquor, piece scouring liquor, and spent dye liquor are produced per working day, and the purification plant consists of seak tanks, magma filters, settling tanks and straining filters. The total capacity of the settling tanks is 31,500 gallons, and the area of the filters 126 square yards.

The analyses refer to average samples taken every hour throughout a working day.

MILL No. 32.

	Parts per 100,000.			
	Mixed crude seak tank liquor from wool and pieces with dye liquor. Before treatment.		Effluent after treatment.	
Appearance of sample	Brown and opaque.		Dark green colour. Transparent.	
Solids in suspension	340·6		11·6	
Loss on ignition		319·27		7·6
Ash		21·33		4·0
Solids in solution	170·7		228·8	
Loss on ignition		101·4		54·0
Ash		69·3		174·8
Alkalinity as H_2SO_4	7·84		1·96	
Fatty matter (extracted by ether)	143·5		0·75	
Total hardness (in terms of $CaCO_3$)	9·3		20·0	

The effluent from the purification plant at this mill is thus a very great improvement on the crude waste before treatment, but it still contains over 11 parts of suspended matter.

Summary as regards Wool Scouring, Piece or Yarn Scouring and Dye Liquors.

At mills where wool scouring liquor occurs in combination with large volumes of piece and dye rinsing water, it is practicable to produce, by careful mixing and good precipitation, a well clarified, non-putrescible effluent which does not take up dissolved oxygen at an excessive rate.

The process involves the use of a considerable quantity of chemicals and good settling tanks, which must be sludged frequently. Some return may be obtained from the sale of the grease.

From the figures for suspended matter obtained in the instances quoted above, we conclude that reduction to 4 parts of suspended solids per 100,000 would probably be practicable in this case.

(5) *Wool Scouring and Piece or Yarn Scouring Liquors.*

65. This combination of waste liquors occurs fairly frequently in the West Riding of Yorkshire, and may, therefore, be referred to here, more especially with a view to showing that treatment in seak tanks alone cannot be considered as a satisfactory form of treatment.

The example which we quote below was brought to our notice by the West Riding of Yorkshire Mill Owners' Association, and the analytical figures were obtained by them for us.

The firm referred to is engaged in the heavy fine-woollen trade, and the waste liquors produced in the process of manufacture are wool scouring liquor, piece scouring liquor, and spent dye liquor. The dye liquors are not dealt with.

The wool scouring liquor and the piece scouring liquor are mixed together and treated in seak tanks for the recovery of grease, the seak tank effluent being sent direct to a stream.

MILL NO. 33.

	Parts per 100,000.			
	Mixed crude wool scouring liquor and piece scouring liquor.		Effluent after treatment.	
Appearance of sample	Blueish-grey, turbid liquid.		Pale, turbid.	
Solids in suspension	294·0		34·0	
Loss on ignition		248·0		26·5
Ash		46·0		7·5
Solids in solution	632·0		573·0	
Loss on ignition		297·0		243·5
Ash		335·0		329·5
Alkalinity in terms of H_2SO_4	260·0		—	
Acidity in terms of H_2SO_4	—		3·9	
Fatty matter (extracted by ether)	475·0		32·0	
Total hardness (in terms of $CaCO_3$)	8·6		190·0	

The effect of the seak tank treatment on this mixture is to remove a large proportion of the greasy suspended matter, but to leave it still greasy and turbid, and at the same time to increase its hardness very greatly indeed.

The effluent would undoubtedly take up much oxygen from water if it were subjected to the 5 days' test.

Summary as regards the Woollen Trade.

A general review of the foregoing results and of the evidence which we have heard from woollen manufacturers and from the West Riding of Yorkshire Mill Owners' and Occupiers' Association leads us to conclude that, except where wool scouring is carried on alone (or, possibly, in conjunction only with piece or yarn scouring), the waste liquors from most mills in the woollen trade can be clarified by precipitation and settlement in tanks, and that treatment to this extent at least is obviously called for.

The effluents produced in this way are liable to be hard, and they cannot be considered pure organically, but they are comparatively free from the foul and greasy suspended matter which causes such objectionable scum and gives rise to putrefying deposits of mud in the slack reaches of rivers.

Our visits to the West Riding, to Lancashire, and to Galashiels and Hawick have led us to conclude that a large number of woollen manufacturers have already provided seak tanks and settling tanks which would, if properly worked and supervised, yield results that might be considered reasonable at the present time.

In very many cases the effluents at present produced are unsatisfactory because the manufacturer takes little interest in the working of the purification plant, and does not trouble to supervise it.

The suds in the seak tanks are sometimes only partially cracked or, on the other hand, too much acid is added, precipitants are misused or not used at all, and tanks are only sludged at intervals of a month or even more, whereas they should never go unsludged for more than a week or a fortnight.

Another point which we cannot too strongly urge relates to the construction of settling tanks. It is quite common to find these separated into units or intersected by baffle walls in such a way as to increase very greatly the rate of flow of the liquor, and so to make the deposition of suspended matter much less complete than it would be, if the tanks were constructed simply with the view of reducing the rate of flow to a minimum or of giving a short period of quiescence.

The precipitation of the greasy liquors with acid in seak tanks is, in our opinion, neither the most satisfactory nor the most economical method of recovering the grease and oil in suds from woollen mills.

As will be seen from the results obtained at Mill No. 23, p. 65, and from the experiments made by us on the precipitation of wool scouring liquor (*cf.* Section III), various coagulants may be used for precipitating suds, and some of these can be recovered again to a large extent. Such chemicals produce a very much better clarification than vitriol or hydrochloric acid.

When grease or oil is recovered from any scouring liquors, we think manufacturers would be wise to consider the replacement of the old forms of grease press by the modern steam-jacketed filter press, and also to turn their attention to the sale of the partially degreased cake.

The Manufacture of Paper and Cardboard.

66. This industry comprises the manufacture of various kinds and qualities of paper, such as writing paper, newspaper, brown paper, blotting paper and wall paper, and of cardboard. As a rule each mill turns out one class of paper only.

The majority of the mills are concentrated in groups, *e.g.*, in Lancashire, Aberdeenshire, Midlothian, the Thames Valley, Kent, and Wilts, but there are also many isolated mills scattered about the country. In by far the greater number of cases the discharge of the waste liquids is into a river or stream.

In the manufacture of paper very large volumes of water are necessary, and the tendency is still further to increase the quantity. In the case of high-class white papers, it is essential that the water shall be quite clean. In several instances that have come to our notice the manufacturer has been forced to purify the river water before use, owing to its polluted and dirty condition. At one mill the cost of this water purification was stated to be £1,000 a year.

A number of different substances are employed in the manufacture, the kind of material varying according to the class of paper turned out by the mill. For high-class writing papers, esparto grass and linen or cotton rags are used, sometimes with the addition of some wood pulp. Newspaper is largely made from wood pulp, whilst brown paper is made from waste paper, old rope and sacking, tarpaulin and peat.

The nature of the waste liquids necessarily varies considerably according to the type of raw material employed. The processes to which the various materials are subjected also differ to some extent.

67. The Rivers Pollution Commission, appointed in 1865, in their First Report (*p.* 18) drew attention to the pollution of the Thames by paper-mill waste liquors.

After pointing out that the alkaline waste liquors are at once the most serious source of injury to rivers and the most difficult to deal with satisfactorily, especially where esparto grass is the raw material, and where soda to the amount of 20 per cent. of the weight of the grass is used, the Commissioners remark that "The argument that it is difficult or impossible to deal with the bulk of the washing water has no application to the first portions of alkaline liquid, the quantity of which is insignificant." They further refer to the evidence on the subject in which "will be found calculations which tend to a belief that the greater part of the alkaline liquor of the paper-maker might, with profit upon the operation, and certainly without much, if any, loss, be so treated as to recover the soda, even in the smallest mills, and under the most unfavourable conditions, and thereby relieve the river of this form of pollution."

It is interesting to note that paper manufacturers do now recover the soda from esparto kier liquor.

The Commissioners further show that in the boiling of the esparto with soda, the greater part of the alkali requisite for the treatment of each ton of material might be readily removed by washing with as little as 3,000 to 4,000 gallons of water.

Again, in the Fourth Report of the Rivers Pollution Commission, pollution from paper-mill waste liquors on the Esk is dealt with (*pp.* 40 and 41) and analyses are given, showing the loss to the paper manufacturer occasioned by permitting the "boilings" and washings to be discharged into a river or stream without purification.

Our own observations have included visits to seventeen mills, typical of the more important kinds of paper manufacture. In a number of instances samples have been taken of the various waste liquors for chemical examination.

The mills visited were representative of the following branches of paper-making:

(1) *Esparto and Rag.*

68. The rags are sorted, cut into fragments, and passed through a machine which removes the dust; the dust is also removed from esparto grass. The materials, whether rag or esparto, are then boiled in closed steel kiers or boilers with a solution of caustic soda, the strength of this solution depending upon the nature of the material. For rags, soda to the amount of 5 to 10 per cent. by weight of the rags is added, whilst for esparto grass as much as 20 per cent. is sometimes used. When the boiling process is completed, the soda solution is run off, the rags washed once whilst still in the kiers, and then sent forward to the washing machine.

We have been informed by a number of manufacturers that the alkaline solutions from rag boiling are too dilute to allow of the profitable recovery of the soda. We have, however, no definite data on this point, and at one mill which we visited the soda is actually recovered.

Esparto grass is usually boiled twice, once in the soda solution and once after the solution has been run off and the kier refilled with clean water. In addition, further quantities of water are added for cooling and washing, before the grass is passed on to the washing machine. The soda solution and the first and second kier washings from esparto grass are now almost invariably evaporated, and the residues incinerated for recovery of the soda. The treatment of rags and esparto from this stage is similar.

The total volume of water used for the boiling and washing of esparto grass in the kiers is not large, amounting to some 3,000 to 4,000 gallons of water per ton of paper produced. In the case of rags it is less.

The rags or esparto are next thoroughly washed with a continuous flow of water in the washer and breaker, the latter process opening up the fibres and reducing the materials to the state known in the trade as "half-stuff."

A very large volume of water is used in the washer and breaker, the first portions of the waste water being very impure.

The "half-stuff" is next bleached with a dilute solution of bleaching powder, which is acidified for the latter part of the time, and the bleached pulp is washed with water. The volume of water used in the actual bleaching process is not large.

After bleaching, the pulp passes through a beating engine, where, if the paper is to be coloured, the necessary colouring matter is added, together with various loading and sizing materials such as china clay, resin, alum, etc.

The pulp is now ready for being made into paper, and is stored in the stuff-chests of the paper-making machine.

The most important part of this machine consists of an endless band of wire cloth, moving in a horizontal plane, and supported at intervals by tube rollers.

The pulp is delivered into a box extending the whole width of the machine, and thence on to the wire band, to which a lateral vibratory motion is imparted by special mechanism, this having the effect of interlacing the fibres whilst still floating in the water.

By the time the layer of pulp nears the end of the machine, most of the water has escaped through the meshes to trays placed under the machine and leading to a storage tank; this liquid is termed "machine-water," and is somewhat large in volume; the bulk of it is generally re-used with fresh pulp. Of recent years it has become the practice to provide fibre-catching machines to deal with the machine water; there are several of these devices in use.

The Füllner "stuffcatcher" consists of a circular tank with conical bottom, provided with a very deep vertical circular metal plate or shell extending to the commencement of the cone and forming a double wall. The machine water enters the tank between the two walls, rises slowly up inside the inner shell, and passes into an overflow channel fixed to the inner shell at the surface. The fibre settles at the foot of the cone, where it is drawn off continuously through a valve to the stuff-chests of the paper machine.

After the wet layer of paper leaves the wire band it passes between various sets of rollers and steam-heated cylinders, finally passing through the calender rolls and being wound on a reel.

The waste liquids produced in the manufacture of high-class papers from rags and esparto consist of the soda boilings and the washings, the waste water from the washer and breaker, the spent bleach liquor and the machine water; there is also a certain quantity of water used at intervals for washing down floors.

The mixed wastes, apart from the strong soda solutions, are generally passed through settling tanks, and the tank liquor is occasionally further clarified by passing it through straining filters.

Very large quantities of sludge are produced, for which, up to the present time, no really satisfactory method of disposal has been found. It is sometimes pressed and tipped, and sometimes dried in lagoons, and subsequently tipped or used to fill up waste land.

Mr. Leonard Tod stated in evidence before the Commission (Q. 29,723) that the amount of refuse resulting from the precipitation of the solid matter from the machines, the bleaching liquor residue, and the carbonate of lime from re-causticising the recovered soda, amounted, in his case, to something like 3,500 cubic yards per annum. When dried, such lime sludge is useful for application to land (*cf.* Hendrick, *Trans. Highland and Agricultural Society*—1914, p. 228).

We may now give a few data and analyses with respect to typical mills at which esparto or rags, or both, are used in the manufacture of high-class papers.

MILL No. 34.

High-class printing and art papers are manufactured at this mill. The total volume of waste liquors discharged from the mill is about 1,500,000 gallons per 24 hours. It comprises the following crude liquids:—

	Gallons per 24 hours.
Esparto wash water - - - -	200,000
Rag-boiling liquor - - - - -	50,000
Rag-washing liquor - - - -	600,000
Machine water (including bleach waste). -	650,000

The esparto kier liquor and the first and second washings are treated for soda recovery. The further washings are mixed with waste water from rag-washing, and run through thirty-six shallow troughs laid in parallel, before being mixed with the rag-boiling liquor and machine water from two machines. The whole is afterwards passed through six tanks, and finally strained through small clinker filters.

The outfall pipe taking this effluent also receives waste machine water from the third machine, after settlement in a separate installation of shallow troughs.

Both sets of troughs are cleaned once a week, the sludge being swept into covered lagoons, and tipped when dry.

The following analyses of waste liquors from this mill were made on average samples covering a period of two days, drawn in January, 1910.

MILL NO. 34.

	No. 182.	No. 183.	No. 184.	No. 185.
	Esparto Wash-water. Average of thirteen samples taken hourly in equal quantities.	Rag-boiling liquor. Average of thirteen samples taken hourly in equal quantities.	Rag-washing water. Average of thirteen samples taken hourly in equal quantities.	General effluent. Average of thirteen sample taken every hour in equal quantities.
	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 31st, 1910.	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 27th, 1910.	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 31st, 1910.	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 27th, 1910.
Parts per 100,000.				
Ammoniacal nitrogen	·03	·36	·10	·10
Albuminoid nitrogen	·11	6·56	·34	·27
Total organic nitrogen	·18	9·20	·91	·43
Nitrous nitrogen	—	—	—	?
Nitric nitrogen	—	—	—	·20
Total nitrogen (Kjeldahl)	·21	9·56	1·01	·73
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.)—				
At once	1·66	26·68	·76	1·42
In 4 hours	14·37	224·7	8·57	10·47
Incubator test (by smell)	Passed (strong sweet smell)		Passed (sweetish smell)	Passed (strong earthy smell)
Total solids	129·3 { 56·4 V. 72·9 N.	831·6 { 451·9 V. 379·7 N.	85·2 { 42·7 V. 42·5 N.	108·2 { 35·4 V. 72·8 N.
Solids in suspension	37·5 { 24·7 V. 12·8 N.	18·8 { 17·2 V. 1·6 N.	39·8 { 27·6 V. 12·2 N.	11·0 { 6·3 V. 4·7 N.
Solids, *i.e.* muds, by centrifuge (vols)	814·5	39·8	575·0	32·9
Fatty acids, extracted by ether after acidifying slightly and evaporating	—	6·9 { 5·7 V. 1·1 N.	—	5·6 { 4·6 V. 0·9 N.
Acidity (as H_2SO_4)	—	15·4 (Volatile organic acid)	—	—
Total alkalinity (as H_2SO_4) (Methyl orange)	17·1*	—	8·9*	12·4
Total hardness (as $CaCO_3$)	—	5·4	—	31·2
Permanent hardness (as $CaCO_3$)	—	2·1	—	26·8
Dissolved oxygen taken up from tap water at 18° C. (65° F.)—				
In 48 hours	2·8	51·2	6·0	3·5
In 5 days	6·2 (3 days)	148·6	8·2 (3 days)	6·9
	Yellowish - brown liquid, with yellow flaky suspended matter in quantity. Strong alkaline and gummy smell when drawn. Very little smell when analysed.	Dark blue turbid liquid, the colour being due to blue rags. Alkaline smell. Not much froth on shaking.	Dark grey-brown liquor, with much fine brown fibrous and very flocculent matter. Alkaline gummy smell.	Darkish turbid liquid with suspended matter, much of which precipitated during sampling. Alkaline gummy smell. Much froth on shaking. A spare bottle of this became putrid on prolonged keeping.

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* In No. 182 and 184 (and, no doubt, 185 also) the alkalinity was due entirely to carbonate.

After the wet layer of paper leaves the wire band it passes between various sets of rollers and steam-heated cylinders, finally passing through the calender rolls and being wound on a reel.

The waste liquids produced in the manufacture of high-class papers from rags and esparto consist of the soda boilings and the washings, the waste water from the washer and breaker, the spent bleach liquor and the machine water ; there is also a certain quantity of water used at intervals for washing down floors.

The mixed wastes, apart from the strong soda solutions, are generally passed through settling tanks, and the tank liquor is occasionally further clarified by passing it through straining filters.

Very large quantities of sludge are produced, for which, up to the present time, no really satisfactory method of disposal has been found. It is sometimes pressed and tipped, and sometimes dried in lagoons, and subsequently tipped or used to fill up waste land.

Mr. Leonard Tod stated in evidence before the Commission (Q. 29,723) that the amount of refuse resulting from the precipitation of the solid matter from the machines, the bleaching liquor residue, and the carbonate of lime from re-causticising the recovered soda, amounted, in his case, to something like 3,500 cubic yards per annum. When dried, such lime sludge is useful for application to land (*cf.* Hendrick, *Trans. Highland and Agricultural Society*—1914, p. 228).

We may now give a few data and analyses with respect to typical mills at which esparto or rags, or both, are used in the manufacture of high-class papers.

Mill No. 34.

High-class printing and art papers are manufactured at this mill. The total volume of waste liquors discharged from the mill is about 1,500,000 gallons per 24 hours. It comprises the following crude liquids :—

	Gallons per 24 hours.
Esparto wash water - - - -	200,000
Rag-boiling liquor - - - - -	50,000
Rag-washing liquor - - - -	600,000
Machine water (including bleach waste). -	650,000

The esparto kier liquor and the first and second washings are treated for soda recovery. The further washings are mixed with waste water from rag-washing, and run through thirty-six shallow troughs laid in parallel, before being mixed with the rag-boiling liquor and machine water from two machines. The whole is afterwards passed through six tanks, and finally strained through small clinker filters.

The outfall pipe taking this effluent also receives waste machine water from the third machine, after settlement in a separate installation of shallow troughs.

Both sets of troughs are cleaned once a week, the sludge being swept into covered lagoons, and tipped when dry.

The following analyses of waste liquors from this mill were made on average samples covering a period of two days, drawn in January, 1910.

MILL No. 34.

	No. 182.	No. 183.	No. 184.	No. 185.
	Esparto Wash-water. Average of thirteen samples taken hourly in equal quantities.	Rag-boiling liquor. Average of thirteen samples taken hourly in equal quantities.	Rag-washing water. Average of thirteen samples taken hourly in equal quantities.	General effluent. Average of thirteen sample taken every hour in equal quantities.
	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 31st, 1910.	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 27th, 1910.	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 31st, 1910.	Drawn Jan. 24th and 25th, 1910. Analysed Jan. 27th, 1910.
Parts per 100,000.				
Ammoniacal nitrogen -	·03	·36	·10	·10
Albuminoid nitrogen -	·11	6·56	·34	·27
Total organic nitrogen -	·18	9·20	·91	·43
Nitrous nitrogen - -	—	—	—	?
Nitric nitrogen - -	—	—	—	·20
Total nitrogen (Kjeldahl)	·21	9·56	1·01	·73
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.)—				
At once - - -	1·66	26·68	·76	1·42
In 4 hours - -	14·37	224·7	8·57	10·47
Incubator test (by smell)	Passed (strong sweet smell)		Passed (sweetish smell)	Passed (strong earthy smell)
Total solids - - -	129·3 { 56·4 V. 72·9 N.	831·6 { 451·9 V. 379·7 N.	85·2 { 42·7 V. 42·5 N.	108·2 { 35·4 V. 72·8 N.
Solids in suspension -	37·5 { 24·7 V. 12·8 N.	18·8 { 17·2 V. 1·6 N.	39·8 { 27·6 V. 12·2 N.	11·0 { 6·3 V. 4·7 N.
Solids, *i.e.* muds, by centrifuge (vols) - -	814·5	39·8	575·0	32·9
Fatty acids, extracted by ether after acidifying slightly and evaporating - - - -	—	6·9 { 5·7 V. 1·1 N.	—	5·6 { 4·6 V. 0·9 N.
Acidity (as H_2SO_4) -	—	15·4 (Volatile organic acid)	—	—
Total alkalinity (as H_2SO_4) (Methyl orange) -	17·1*	—	8·9*	12·4
Total hardness (as $CaCO_3$)	—	5·4	—	31·2
Permanent hardness (as $CaCO_3$) - - -	—	2·1	—	26·8
Dissolved oxygen taken up from tap water at 18° C. (65° F.)—				
In 48 hours - -	2·8	51·2	6·0	3·5
In 5 days - - -	6·2 (3 days)	148·6	8·2 (3 days)	6·9
	Yellowish - brown liquid, with yellow flaky suspended matter in quantity. Strong alkaline and gummy smell when drawn. Very little smell when analysed.	Dark blue turbid liquid, the colour being due to blue rags. Alkaline smell. Not much froth on shaking.	Dark grey-brown liquor, with much fine brown fibrous and very flocculent matter. Alkaline gummy smell.	Darkish turbid liquid with suspended matter, much of which precipitated during sampling. Alkaline gummy smell. Much froth on shaking. A spare bottle of this became putrid on prolonged keeping.

* In No. 182 and 184 (and, no doubt, 185 also) the alkalinity was due entirely to carbonate.

Excepting for the amount of solids in suspension (37·5 parts), which were very flocculent, the esparto wash water was a much less polluting liquid than might have been expected.

The rag-boiling liquor was excessively impure, with 832 parts of solids in solution, of which 452 parts were volatile on ignition, but only 18·8 parts of solids in suspension. It contained a very large quantity of oxidizible matter, and took up 148·6 parts of dissolved oxygen in 5 days. The rag-washing water was comparable with the esparto wash-water, its main impurity being 39·8 parts of very flocculent suspended matter.

Laboratory experiments made at Ealing showed that, mixed with diluted sewage, neither the esparto wash-water nor the rag-washing water had any serious retarding effect as regards the absorption of dissolved oxygen by the mixture.

The general effluent contained 11 parts of suspended solids, more than half of which was organic matter, and, for a final effluent, it was not of high quality, both on account of these solids and because it took up 6·9 parts of dissolved oxygen in 5 days. Still, it was non-putrescent on incubation for 5 days—a noteworthy point when taken in conjunction with the other figures.

Mill No. 35.

Only high-class papers are manufactured at this Mill, esparto, rags and wood pulp being the raw materials.

The total flow of waste liquids amounts to about 500,000 gallons per 24 hours.

It is dealt with as follows:—

The final waste waters from the esparto kiers, the rag boiling and washing water, the washings from the wood pulp after bleaching and the "pressepate" water are mixed together and settled in two large ponds (total capacity 500,000 gallons), used in parallel. The settled liquor thus obtained is mixed with a small quantity of cesspool drainage and then allowed to flow through two more settling tanks (total capacity about 230,000 gallons), used in series, before being sent in flushes on to percolating filters. There are three of these filters, each 51 feet in diameter and 8 feet deep, composed of medium to coarse clinker.

The volume of liquor treated in this way is about 276,000 gallons per day.

Allowing for the week-end stoppage of the works, the average rate of flow through the filters is about 120 gallons per cube yard per day.

The machine waters are settled separately, and strained through two straining beds, each measuring 187 feet by 50 feet by 3 feet 9 inches deep.

The following analyses relating to this mill were made on chance samples drawn in February, 1911 and October and November, 1913, and on average samples drawn in February, 1914.

Mill No. 35.

	No. 251.		No. 252.		No. 253.		No. 254.		No. 255.		No. 256.		No. 1.		No. 2.		No. 10.		No. 11.		No. A.		No. B.	
	Crude machine water.		Settled machine water from upper ponds.		Filter-strained machine waters from upper ponds.		Washings from esparto and spent bleach liquors.		Settled liquor just before going on to filter.		Percolating filter effluent.		Esparto tank liquor, as flowing from sprinkler arms on to percolating filter.		Effluent from No. 2. percolating filter.		Tank liquor, drawn from sprinkler arms.		Percolating filter effluent.		Tank liquor as flowing on to filters, Average sample, taken in equal quantities every half hour, from 7.0 a.m. to 4.0 p.m.		Filter effluent. Average sample, taken in equal quantities every half hour from 7.0 a.m. to 4.0. p.m	
	Drawn Feb. 2nd, 1911. Analysed Feb. 6th, 1911.		Drawn Feb. 2nd, 1911. Analysed Feb. 6th, 1911.		Drawn Feb. 2nd, 1911. Analysed Feb. 6th, 1911.		Drawn Feb. 2nd, 1911. Analysed February 6th, 1911.		Drawn Feb. 2nd, 1911. Analysed February 3rd, 1911.		Drawn Feb. 2nd, 1911. Analysed February 3rd, 1911.		Drawn Thursday, Oct. 30th, 1913, 12.0 noon. Analysed Nov. 3rd, 1913.		Drawn Oct. 30th, 1913, 12.15 noon. Analysed Nov. 3rd, 1913.		Drawn Monday, Nov. 10th, 1913. 4.0 p.m. Analysed Nov. 12th, 1913.		Drawn Nov. 10th, 1913, 4.15 p.m. Analysed Nov. 12th, 1913.		Drawn, Wednesday, Feb. 4th, 1914. Analysed February 6th, 1914.		Drawn, Wednesday Feb. 4th, 1914. Analysed February 6th, 1914	
Parts per 100,000.		P.F.†		P.F.		P.F.		P.F.		P.F.		P.F.										P.F.		P.F.
Ammoniacal nitrogen	·011	·011	·018	·018	·014	·014	·34	·34	·20	·20	·044	·044	0·14	—	0·07	—	0·11	—	0·08	—	0·12	—	0·07	—
Albuminoid nitrogen	·033	·021	·023	·023	·07	·04	·16	·10	·22	·17	·105	·073	0·21	—	0·17	—	0·17	—	0·15	—	0·13	—	0·10	—
Total organic nitrogen	—	—	—	—	—	—	0·41	—	0·53	—	—	—	0·37	—	0·42	—	0·29	—	0·28	—	0·18	—	0·20	—
Nitrous nitrogen	·00	·00	·00	—	·00	—	·00	—	·00	—	·00	—	—	—	—	—	—	—	—	—	0·0	—	0·0	—
Nitric-nitrogen	·10	—	·11	—	·10	—	·04	—	·00	—	·055	—	—	—	—	—	—	—	—	—	0·03	—	0·03	—
Total nitrogen (Kjeldahl)	—	—	—	—	—	—	0·79	—	0·73	—	—	—	0·51	—	0·49	—	0·40	—	0·36	—	0·33	—	0·30	—
Oxygen absorbed from N/8 permanganate at 80° F.—																								
At once	—	—	—	—	—	—	—	—	—	—	—	—	2·31	—	2·43	—	1·92	—	1·75	—	1·55	—	1·55	—
In 4 hours	8·01	3·31	3·70	3·15	3·87	3·39	26·92	13·94	12·64	9·67	4·96	4·09	13·5	—	11·71	—	12 92	—	10·27	—	11·30	8·66	8·97	6·67
Incubator test (by smell)	(?) Musty smell		Not done.		Not done		Passed		Failed		Failed (putrid, trace of H_2S).		—	—	—	—	—	—	—	—	—	—	Passed	
Solids in suspension	84·6 { 45·2 V. 39·4 N.		3·8 { 1·5 V. 2·3 N.		2·4 { 0·4 V. 2·0 N.		90·4 { 70·4 V. 20·0 N.		10·6 { 5·6 V. 5·0 N.		5·2 { 3·0 V. 2·2 N.		15·6 { 9·2 V. 6·4 N.		12·4 { 8·2 V. 4·2 N.		9·4 { 5·8 V. 3·6 N.		4·8 { 3·2 V. 1·6 N.		10·8 { 5·8 V. 5·0 N.		2·5 { 2·5 V. 0·0 N.	
Solids (*i.e.*, muds) by centrifuge (vols.)	662·0	—	17·0	—	3·6	—	50·9	—	12·4	—	48·6	—	—	—	—	—	—	—	—	—	—	—	—	—
Total alkalinity (as H_2SO_4) (Me.O.)*	15·5	13·7	14·7	14·2	15·7	14·8	26·2	18·6	31·3	28·8	—	24·8	24·4*	—	27·2*	—	23·1*	—	24·4*	—	27·6*	—	28·9*	—
Total hardness (as $CaCO_3$)	49·3	—	49·3	—	58·4	—	64·1	—	63·7	—	51·5	—	—	—	—	—	—	—	95·7	—	68·1	—	65·8	—
Permanent hardness (as $CaCO_3$)	39·3	—	36·5	—	44·5	—	48·6	—	41·0	—	25·7	—	—	—	—	—	—	—	72·9	—	47·2	—	42·9	—
Dissolved oxygen taken up from tap-water at 18° C. (65° F.) —																								
In 24 hours	·00	·06	·12	·00	·35	·00	—	—	4·7	3·9	·31	·20	—	—	—	—	—	—	—	—	—	—	—	—
In 48 hours	·53	·25	·62	·56	·97	·72	‡3·25	—	7·2 + x	7·3	1·25	·99	8·83	—	6·44	—	3·75	—	3·43	—	6·78§	—	5·43§	—
In 5 days	5·18	4·95	4·37	4·12	4·05	3·45	‡7·70	—	13·9	11·9	2·42	1·82	18·10	—	11·88	—	9·80	—	8·35	—	12·10	11·60	7·60	8·40
Notes on Samples	Somewhat turbid. Colourless. Much fine flocculent solids. Very slight musty smell.		Turbid and colourless. Not very much cellulose in suspension. Slight musty smell.		Colourless; very opalescent. No large solids. No smell.		Yellow-brown and very turbid, with yellow-brown solids. Spent bleach smell. Alkaline. Traces of chlorine on acidifying.		Yellow-brown and turbid. Septic smell. Little H_2S. Small amount of suspended solids.		Brown in colour and moderately opalescent. Considerable amount of fine light-brownish solids. Slight earthy smell.		Brownish and turbid. Stale septic odour. Much H_2S.		Brownish and turbid; did not look much better than No. 1. Solids finely divided. Septic smell. Considerable H_2S.		Brownish and turbid. Slightly stale odour with a little H_2S.		Brownish and turbid, but slightly clearer than No. 10. Soapy sewage smell. Very little H_2S.		Brownish and opalescent. Light-coloured suspended matter. Slight kier odour.		Brownish an opalescent, bu slightly cleare than A. Fin light-coloure solids. Sligh kier odour.	

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* None of these last six samples contained any caustic alkali. The point was not noted in the case of the first six.

† "P.F." means paper-filtered sample.

‡ February 9th. Sample bottle now only one-quarter full.

§ 3 Days.

The crude, settled, and filter-strained machine waters, Nos. 251, 252 and 253, contained 84·6, 3·8 and 2·4 parts of suspended solids, and took up 5·18, 4·37, and 4·05 parts of dissolved oxygen in 5 days. They may thus be regarded as rather weak liquids. The washings from the esparto and spent bleach liquor were much more polluting. The settled liquor, No. 255, just before going on to the percolating filter, contained 10·6 parts of suspended solids, and took up 13·9 parts of oxygen in 5 days. In the percolating filter effluent, No. 256, these solids were reduced to 5·2 parts, and the dissolved oxygen absorption to 2·4. Although this effluent failed to withstand the incubator test, it was of fairly good quality.

Taking all the samples of tank liquor—Nos. 255, 1, 10, and A—together, these were on the whole very similar in character. The last of them, No. A, was an average sample, drawn over a working day, and may therefore be regarded as typical. The impurity in it was mainly carbonaceous; it contained 10·8 parts of suspended solids and took up 12·1 parts of dissolved oxygen in 5 days, this absorption of oxygen being due to the matter in solution and not in suspension.

The average sample of filter effluent, No. B, was better than the corresponding tank liquor A, the suspended solids being reduced to 2·5 parts (all organic) and the dissolved oxygen absorption in 5 days to 7·6 parts; here, again, this absorption of oxygen was due to the matter in solution. This effluent withstood the incubator test, *i.e.*, it gave rise to no offensive smell on incubation for five days, notwithstanding its power of taking up dissolved oxygen from water. It was distinctly hard. The chance samples of filter effluent, Nos. 256, 2 and 11, varied materially in quality, the first being much better than the other two, which were but little different from the tank liquors drawn at the same time.

Speaking generally, the percolating filter did not in this case effect a very great purification.

Sludge.—A sample of sludge from this mill was examined. The sample was taken from the first settling tank as the sludge was being pumped to a lagoon.

Sample drawn - - - Feb. 4th, 1914
„ analysed - - Feb. 27th, 1914

	Parts per cent.
Moisture	93·85
Dry matter	6·15
	100·0
Matter volatile on ignition	5·04
Matter non-volatile „	1·11
	6·15
Nitrogen (N_2)	0·019 ; 0·009
Phosphoric Acid (P_2O_5)	0·019
Mineral matter insoluble in hydrochloric acid (ignited)	0·39
Oxide of iron and alumina	0·20
Lime (CaO)	0·32

Sludge such as this, after drying, should have some calorific value.

Mill No. 36.

At this mill high-class magazine and printing papers are manufactured from esparto grass and wood-pulp.

The total volume of waste liquors produced is about 250,000 gallons per 24 hours.

The kier liquor and the first two washings are treated for soda recovery, whilst the third and fourth wash-waters are partly neutralised with acid, and then precipitated with alumino-ferric before being mixed with the general waste liquors from the mill.

The whole of the mixed waste liquors are then passed continuously through a number of small settling tanks, and finally strained through coarse clinker filters, before being discharged into a small stream.

The total tank capacity is 180,000 gallons. The total filter capacity is about 37 cubic yards.

The following figures of analysis relate to chance samples of final effluent drawn in January and February, 1911.

Mill No. 36.

	No. 1.		No. 2.		No. 3.	
	Effluent.		Effluent.		Effluent.	
	Drawn Jan. 25th, 1911, 2.0 p.m. Analysed Jan. 31st, 1911.		Drawn Jan. 26th, 1911, 11.0 a.m. Analysed Feb. 1st, 1911.		Drawn Jan. 26th, 1911, 3.30 p.m. Analysed Feb. 1st, 1911.	
Parts per 100,000.		P.F.		P.F.		P.F.
Ammoniacal nitrogen - -	·07	·07	·11	·11	·15	·15
Albuminoid nitrogen - -	·14	·11	·15	·13	·17	·16
Total organic nitrogen - -	·34	—	·41	—	·45	—
Nitrous nitrogen - - -	·00	—	·00	—	·00	—
Nitric nitrogen - - -	·04	—	·20	—	·20	—
Total nitrogen (Kjeldahl) - -	·44	—	·72	—	·80	—
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.)—						
In 4 hours - - - -	15·14	11·28	22·91	16·70	21·25	16·37
Incubator test (by smell) - -	Passed		Passed (slight bleach smell).		Passed	
Solids in suspension - - -	23·9 { 9·1 V. 14·8 N.		20·0 { 10·0 V. 10·0 N.		20·5 { 9·4 V. 11·1 N.	
	The Gooch filtrate was rather opalescent. By Feb. 21st more solids had come down, viz.— 5·8 { 4·6 V. 1·2 N. The filtrate was then bright and clear.		The Gooch filtrate was opalescent. By March 24th further solids had come down, viz.— 6·0 { 6·0 V. 0·0 N. The filtrate was then clear.			
Solids (*i.e.*, muds) by centrifuge (vols.)	23·6	—	20·9	—	22·4	—
Total alkalinity (as H_2SO_4) (Me.O.)	11·8	5·9	11·9†	7·9†	9·9	10·7
Total hardness (as $CaCO_3$) -	78·3	—	63·5	—	62·7	—
Permanent hardness (as $CaCO_3$)	75·1	—	58·3	—	59·5	—
Dissolved oxygen taken up from tap water at 18° C.(65° F.)—						
In 24 hours - - - -	—	—	0·0	0·96	—	—
In 48 hours - - - -	2·0	2·30	5·2	3·62	1·90	2·40
In 5 days - - - -	8·64*	8·64*	12·8	11·6	11·80	8·20
	Pale yellowish-brown, and very turbid and frothy. Spent bleach smell. Much very fine suspended matter (largely carbonate of lime).		Very brownish and turbid. Much fine sediment. Strong spent bleach smell. No free chlorine or hypochlorite present.		Yellow - brown, very turbid and frothy. Very faint spent bleach smell. Alkaline. No free chlorine, but a trace of hypochlorite.	

* 6 days.

† Approximate figures.

MILL NO. 36.

	No. 4.	No. 5.		No. 6.	
	Effluent.	Effluent.		Effluent.	
	Drawn Feb. 3rd, 1911, 9.0 a.m. Analysed Feb. 7th, 1911.	Drawn Feb. 3rd, 1911, 11.30 a.m. Analysed Feb. 7th, 1911.		Drawn Feb. 3rd, 1911.* Analysed Feb. 7th, 1911.	
Parts per 100,000.			P.F.		P.F.
Ammoniacal nitrogen	—	·12	·12	·17	·18
Albuminoid nitrogen	—	·16	·13	·28	·23
Total organic nitrogen	—	·62	—	·72	—
Nitrous nitrogen	—	·00	—	·00	—
Nitric nitrogen	—	·00	—	·20	—
Total nitrogen (Kjeldahl)	—	·74	—	1·05	—
Oxygen absorbed from N/8 permanganate at 27°C. (80°F.)— In 4 hours	—	22·65	17·12	36·89	28·00
Incubator test (by smell)	—	Passed		Passed (slight spent bleach smell)	
Total solids	—	—	—	—	—
Solids in suspension	18·7 { 7·2 V. 11·5 N.	20·0 { 9·4 V. 10·6 N.		32·0 { 15·5 V. 16·5 N.	
Solids (*i.e.*, muds) by centrifuge (vols.)	31·5	62·0	—	38·5	—
Total alkalinity (as H_2SO_4)(Me.O.)	—	11·1	9·7	19·9 approx. ;	9·3
Total hardness (as $CaCO_3$)	—	79·9	—	79·8	—
Permanent hardness (as $CaCO_3$)	—	78·2	—	67·3	—
Dissolved oxygen taken up from tap water at 18° C. (65° F.)— In 24 hours	—	3·36	2·90	0·46	0·74
In 48 hours	—	7·00	4·60	6·32	2·22
In 5 days	—	11·60	13·0	20·36	16·68
		Yellow-brown. Very turbid and frothy. Much very fine suspended solids. Spent bleach smell. Alkaline. No free chlorine on acidifying.		Very brown and turbid, with considerable fine deposit. Strong odour of spent bleach. No free chlorine or hypochlorite.	

* Hour of sampling not noted.

These figures of analysis show that the effluent contained considerable quantities of nitrogenous matter and about 20 parts of suspended solids, and that it took up 8·6 to 20·4 parts of oxygen from water in 5 days. The paper-filtered samples took up from 8·2 to 16·7 parts of oxygen, hence the absorption was for the most part due to matter *in solution.* Notwithstanding this, the effluent gave rise to no offensive smell on incubation for five days.* Its alkalinity was not great, but the figure for hardness averaged 60 to 70 per 100,000.

Mill No. 37.

Here printing paper is manufactured from esparto and wood-pulp.

The total volume of waste liquors amounts to some 250,000 gallons per 24 hours.

The kier liquor is evaporated and treated for soda recovery. A "Füllner" apparatus is used for the recovery of fibre.

The waste liquors from the breaking machines and "Füllner" pulp recovery apparatus are mixed and passed through a series of settling tanks, having a total capacity of 73,000 gallons.

The sludge is pressed and tipped.

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* Samples 2 and 6 were also incubated after inoculation with a few drops of sewage, but they had only a slight odour of spent bleach after the incubation.

The following figures of analysis relate to chance samples of final effluent, drawn in December, 1910, and November, 1913.

MILL No. 37.

	No. 1.		No. 2.	
	Final effluent.		Final effluent.	
Drawn	December 22nd, 1910.		Wednesday, Nov. 19th, 1913, 10.45 a.m.	
Analysed	January 2nd, 1911.		November 21st, 1913.	
Parts per 100,000.		P.F.		
Ammoniacal nitrogen	0·02	·02	0·09	—
Albuminoid nitrogen	0·03	·02	0·07	—
Total organic nitrogen	0·04	—	0·14	—
Nitrous nitrogen	0·0	—	0·0	—
Nitric nitrogen	0·22	—	0·27	—
Total nitrogen (Kjeldahl)	0·37	—	0·50	—
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.)—				
At once	—	—	0·66	—
In 4 hours	2·37	2·04	2·78	—
Incubator test (by smell)	* Earthy, paper smell.		—	—
Solids in suspension	*11·1 { 2·7 V. 8·4 N.		19·8 { 8·9 V. 10·9 N.	
Solids (*i.e.*, muds) by centrifuge (vols.)	34·2 (December 24th)		—	—
Total hardness (as $CaCO_3$)	94·5	—	65·1	—
Permanent hardness (as $CaCO_3$)	84·7	—	55·3	—
Dissolved oxygen taken up from tap water at 18° C. (65° F.):—				
In 48 hours	·17	—	0·08 (3 days)	—
In 5 days	·28	·29	0·73	—
	Colourless and clear. Much flocculent white suspended matter (cellulose). Slight paper smell. Considerable frothing on shaking.		Bright and clear like water, but with much flocculent paper pulp, etc. in suspension.	

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* Three other estimations of suspended solids gave :—on December 24th, 1910, 5·6 parts, and on Jan. 5th, 1911, 9·9 and 10·4 parts. These differences were no doubt caused by the deposition of carbonate of lime from the liquid.

It will be seen that this effluent is of a different class from that of Mill No. 34, being derived from the waste water of the breaking machines alone, *i.e.*, from a very much weaker crude liquor. It contained very little organic impurity, and therefore took up almost no oxygen, but it was very hard. Sample No. 1 was well oxygenated when analysed ; this would no doubt apply to No. 2 also, but its oxygen in solution was not determined.

The suspended matter which the samples contained was mainly carbonate of lime, together with paper pulp.

MILL NO. 38.

Blotting paper of various colours, wall-papers and machine-glazed papers are made here, the raw materials in this case being rags and wood-pulp with some jute and hair.

At this mill soda is recovered from the rag boilings.

The total flow of general or mixed effluents is about 1,000,000 gallons per 24 hours, and it is made up of (1) water from rag breaker; (2) machine water; (3) drainings from the bleached pulp.

There is also a certain amount of semi-solid residue, mainly carbonate of lime, derived from making up the bleach solution and from the causticising process.

The waste liquors, apart from the rag-washing water, are mixed together and passed through a series of eight tanks, having a total combined capacity of about 163,600 gallons.

The tanks are seldom cleaned out; when the sludge is removed it is lagooned, and deposited on waste ground.

The rag-washing liquor, amounting to about 500,000 gallons per day, is treated separately, being settled in a pond having a capacity of about 58,000 gallons. From this it is discharged to the river.

The following samples, which were averages of 12 hours each, drawn in equal quantities every hour, show the character of the crude rag-washing liquor, and the general waste liquor before and after settlement.

MILL NO. 38.

	No. 186.	No. 187.	No. 188.
	Rag-washing liquor—12 hours average sample.	General waste liquor—12 hours average sample.	General tank effluent—12 hours average sample.
	Drawn Jan. 28th, 1910. Analysed Feb. 7th, 1910.	Drawn Jan. 28th, 1910. Analysed Feb. 3rd, 1910.	Drawn Jan. 28th, 1910. Analysed Feb. 3rd, 1910
Parts per 100,000.			
Ammoniacal nitrogen - -	0·31	0·08	0·15
Albuminoid nitrogen - -	3·09	0·67	0·45
Total organic nitrogen - -	5·74	1·52	0·98
Nitrous nitrogen - - -	—	--	} 0·18
Nitric nitrogen - - -	—	—	
Total nitrogen (Kjeldahl) -	6·05	1·60	1·31
Oxygen absorbed from N/8 permanganate at 27°C. (80°F.)—			
At once - - - - -	18·07	2·83	1·27
In 4 hours - - - -	97·15	17·67	9·03
Incubator test (by smell) - -	—	—	Passed (strong odour of spent bleach)
Total solids - - - -	529·2 { 266·0 V. 263·2 N.	327·4 { 150·4 V. 177·0 N.	95·7 { 23·0 V. 72·7 N.
Solids in suspension - - -	*217·8 { 162·4 V. 55·4 N.	96·4 { 48·8 V. 47·6 N.	16·2 { 3·4 V. 12·8 N.
Solids (*i.e.*, muds) by centrifuge (vols.)	—	683	102·7
Fat, extracted by ether - -	8·6 { 8·2 V. 0·4 N.	6·6 { 6·4 V. 0·2 N.	2·5 approx. { 2·5 V. 0·0 N.
Total alkalinity (as H_2SO_4)(Me.O.)	133·5	21·8	36·4
Total hardness (as $CaCO_3$) -	7·8	33·5	43·1
Permanent hardness (as $CaCO_3$)	2·0	25·3	31·5
Dissolved oxygen taken up from tap water at 18° C. (65° F).—			
In 48 hours - - - -	35·1	7·75	2·47
In 5 days - - - -	98·0	19·35	7·64
Remarks - - - -	Very dark brown and turbid, with much fibre and large lumps of rag. Bitter alkaline smell. Not much froth on shaking.	Very brown and turbid, with much fibre in suspension. Smell of spent bleach and gummy substances. Much froth on shaking.	Brown liquor, with much fine fibre in suspension. Spent bleach and gummy smell. Much froth on shaking.

* The Gooch filtrate was very colloidal.

The rag-washing liquor was a highly impure and rather alkaline liquor, containing as much as 218 parts of suspended solids, together with some further colloidal matter. The organic matter was mainly carbonaceous.

The general waste liquor contained a considerable quantity of nitrogenous organic matter and 96 parts of suspended solids. It took up as much as 19 parts of dissolved oxygen in 5 days.

The general effluent still contained a good deal of nitrogenous organic matter and 16·2 parts of suspended solids, while it took up 7·6 parts of dissolved oxygen in 5 days. It was only moderately hard, and withstood incubation without giving rise to an offensive odour.

Summary as regards the Waste Liquors from Paper Mills where Esparto and Rags are used, frequently together with Wood Pulp.

As will be seen from the figures of analysis given above, this waste varies very much in quality at different paper mills.

It is a turbid, gummy, alkaline liquor, containing finely divided suspended matter difficult to settle, and it may be looked upon as being somewhat similar to bleach works waste, but usually much weaker. The volume is generally very large.

At one mill, No. 33, a purification plant has been provided which includes not only settling tanks but large percolating filters, 8 feet deep, which are fed by revolving sprinklers.

The purification effected by these filters is relatively much less than it would be with domestic sewage, and since this is the best example of treatment that we know, we are led to infer that there is at present no practical method for efficiently purifying this class of waste liquor.

Systematic experiments on a large scale are required.

Until this has been done we can only suggest clarification as a partial remedy.

The figures for suspended matter in the final effluents to which we have referred vary from 2·5 to 32·0, but our general experience leads us to think that reduction to 6 parts could probably be attained in the majority of cases.

(2) *Wood-Pulp Mills.*

69. Wood-pulp is used mainly for cheap papers, such as newspaper.

Nearly the whole of the wood-pulp is imported from Canada and Scandinavia, in the form of compressed pulp. There are very few mills in this country at the present time manufacturing the pulp from the wood itself by means of the sulphite process. Two mills were visited, however, where the process is carried out in its entirety, and they are described in Section III.

Wood-pulp is imported in two forms, "mechanical" and "chemical" pulp; the latter does not require bleaching.

The wood-pulp does not need to be subjected to the soda boiling process; it is usually ground up, washed, bleached and re-washed, before passing from the beater to the paper machine.

MILL No. 39.

The following analyses of two chance samples show the nature of the general effluent from a wood-pulp mill.

At this mill, where newspaper is manufactured from wood-pulp, the total volume of waste liquor amounts to about 750,000 gallons daily, comprising waste waters from beating, bleaching, and paper machines.

The whole of the waste liquors are mixed and first settled in two large tanks, receiving final settlement in a large water lodge.

As the crude liquors are entirely made up of water from bleaching, beating, and the paper machines, and only cheap paper is manufactured, the pulp settling in the tank as sludge can be re-used for paper making; it is pumped from the tanks, pressed, and then mixed with fresh wood-pulp.

About 40 tons of the pressed cake are produced weekly. At the end of the week, when the floors of the mill are washed, the sludge settling in the tanks is too dirty for re-use, and it is sent to the tip.

The following analyses relate to two chance samples of the final effluent from this Mill :—

Mill No. 39.

	No. A.		No. B.	
	Effluent.		Effluent.	
	Drawn Dec. 14th, 1910. Analysed Dec. 19th, 1910.		Drawn Dec. 16th, 1910. Analysed Dec. 19th, 1910.	
Parts per 100,000.		P.F.		P.F.
Ammoniacal nitrogen - - - - - -	·01	·01	·01	·01
Albuminoid nitrogen - - - - - -	·02	·02	·02	·01
Total organic nitrogen - - - - - -	·10	—	·09	—
Nitrous nitrogen - - - - - - -	·00	—	·00	—
Nitric nitrogen - - - - - - -	·02	—	·08	—
Total nitrogen (Kjeldahl) - - - - -	·15	—	·20	—
Oxygen absorbed from N/8 permanganate at 27°C. (80° F.)—				
In 4 hours - - - - - - - - -	1·29	1·10	1·0	0·92
Incubator test (by smell) - - - - -	Passed (no smell)		Passed (no smell)	
Solids in suspension - - - - - -	1·1	0·4 V. 0·7 N.	1·1	0·9 V. 0·2 N.
Solids (*i.e.* muds) by centrifuge (Vols.) - - -	26·2	—	25·2	—
Total hardness (as $CaCO_3$) - - - - -	16·2	—	15·6	—
Permanent hardness (as $CaCO_3$) - - - -	14·2	—	14·8	—
Dissolved oxygen taken up from tap water at 18°C. (65° F.)—				
In 48 hours - - - - - - - - -	·11	·11	·19	·11
In 5 days - - - - - - - - -	·63	·44	·49	·43
	Almost clear and colourless. Considerable white and very flocculent suspended matter (cellulose). No smell.		Almost clear and colourless. Considerable flocculent white suspended matter (cellulose). Very little smell.	

This effluent was of excellent quality—containing only traces of nitrogenous matter, about 1 part of suspended solids, and taking up hardly any dissolved oxygen in 5 days. It was also well oxygenated when analysed. This result was obviously due, in the main, to the comparative harmlessness of the raw material. The effluent deposited hardly any further solids on standing.

Summary as regards the Waste Liquor from Paper Mills where Wood Pulp is used alone.

In this case the impurity consists almost entirely of fine particles of fibre in suspension, and good settlement of the waste liquor is all that is required. The fibre thus removed can frequently be used again for the manufacture of slightly coloured paper.

In his evidence, given before us on January 27th, 1909, Mr. Halliwell handed in a table containing amongst other figures those for suspended matter in the final effluents from three wood pulp paper mills in the Ribble Watershed, the figures ranging from 0·2 to 3·8, with an average of 1·8.

It is thus obvious that the suspended solids in such effluents can in practice be reduced to a low figure, which we think might be put at 4 parts per 100,000.

(3) *Brown Paper.*

70. In the manufacture of brown paper, the character of the raw materials used is largely responsible for the dirty and impure character of the waste liquors. In place of the "soda boil" used for esparto and rags, the materials are frequently boiled with lime in kiers, to remove grease and dirt. The kier liquors—whether containing lime or soda—are not usually treated for recovery.

MILL No. 40.

At this mill, brown, blue, and buff papers are manufactured for making into paper bags, the materials employed being waste paper, old tarpaulin, peat, jute, etc.

The waste liquor is derived mainly from the breaking machines, but with brown paper, instead of the waste being almost colourless or bright yellow it is dark brown, and heavily charged with suspended solids.

The whole of the waste waters at this mill are mixed and passed continuously through a series of tanks having a capacity of 74,000 gallons, the tank liquor being subsequently streamed through two small clinker filters, having a total area of 346 square yards.

A chance sample of effluent from this works gave the following figures on analysis :—

MILL No. 40.
Final effluent (chance sample).

Drawn - - - - - - - - - - - - - Tuesday, January 6th, 1914.
Analysed - - - - - - - - - - - - - - January 8th.

Parts per 100.000.		Sample after filtration through paper.	Sample after precipitation with alumino-ferric equivalent to 3 parts Al_2O_3 + 8 parts lime (CaO), and paper-filtration.
Ammoniacal nitrogen	0·25	—	—
Albuminoid nitrogen	0·63	—	—
Total organic nitrogen	1·25	--	—
Nitrous nitrogen	(?)	—	—
Nitric nitrogen	0·19	—	—
Total nitrogen (Kjeldahl)	1·69	—	—
"Oxygen absorbed" from N/8 permanganate at 27° C. (80° F.)—			
At once	3·96	—	—
In 4 hours	21·50	19·0	17·0
Incubator test (by smell)	Failed (H_2S)		
Solids in suspension	16·3 { 7·1 V. 9·2 N.	--	—
Total alkalinity, as H_2SO_4	18·3	—	—
Caustic alkalinity, as H_2SO_4	2·6	—	—
Total hardness, as $CaCO_3$	90·0	—	—
Permanent hardness, as $CaCO_3$	84·3	—	—
Dissolved oxygen taken up from tap-water at 18° C. (65° F.)—			
In 48 hours	9·36	—	--
In 5 days	27·2	25·4	—
Notes	Brownish and turbid, with considerable finely-divided dark-coloured suspended matter. Very frothy. Slight spent bleach smell.		

The following figures are taken from two analyses, kindly supplied to us by Mr. Scudder; they show the composition of the waste before and after treatment:—

Mill No. 40.

	Drawn July 21st, 1910.	Drawn July 21st, 1910.
	Before treatment.	After treatment.
Parts per 100,000.		
Free and Saline ammonia	·25	·26
Albuminoid ammonia	2·04	·63
Oxygen absorbed from permanganate at 60° F.—		
In 3 minutes	29·1	6·5
In 4 hours	73·0	17·0
Solids in suspension	360·0 178 V. 182 N.	5·5 3·5 V. 2·0 N.
Solids in solution	345·4 125·4 V. 220·0 N.	292·4 68·0 V. 224·4 N.
Alkalinity		
(*a*) Free sulphuric acid required to neutralise (Phenol-phthaleïn)	none	32·3
(*b*) Total sulphuric acid required to neutralise (Litmus boiling)	123·4	61·7
Dissolved oxygen taken up at 75·5° F.—		
In 24 hours	3·4	1·08
In 48 hours	—	1·2
Chlorine	14·3	33·5
	Brown turbid liquid. Dark coloured sediment. Slight smell.	Light yellowish coloured liquid. Greyish sediment. Smell of waste bleach.

The Chlorine figures indicate that the two last were not corresponding samples. The waste before treatment was a very polluting liquor, mainly because of the large amount of suspended solids present. In the waste, after treatment, although the suspended solids were reduced to 5·5 parts, the effluent was still far from pure.

The chance sample of effluent drawn by ourselves was also very polluting. It took up 27 parts of dissolved oxygen in 5 days, this being due almost entirely to the matter in solution and colloidal solution, and only in small degree to the suspended solids present. It contained considerable nitrogenous matter, putrefied on incubation and was very hard.

The following analytical results were handed in by Mr. Edward Halliwell, Chief Inspector to the Ribble Joint Committee, when giving evidence before us on January 27th, 1907. They refer to brown paper mills situated in the Ribble watershed.

ANALYTICAL TABLES HANDED IN BY MR. EDWARD HALLIWELL, CHIEF INSPECTOR TO THE RIBBLE JOINT-COMMITTEE.

Parts per 100,000.

Sample No.	Taken.		Suspended solids.			Dissolved solids.			Ammonia.		Oxygen absorbed.			In solution only.			After incubation.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.	Free.	Albuminoid.	In 15 Minutes.	In 3 Minutes.	In 4 hours.	Albuminoid ammonia.	Oxygen absorbed. In 3 minutes.	Oxygen absorbed. In 4 hours.	Oxygen absorbed in 3 minutes	Odour.
		MILL NO. 41.—BROWN PAPER.																
W.	Jan. 10, 1907	Crude liquids	105	101	206	66	85	151	—	—	—	8·9	—	—	2·8	—	8·7	No H_2S.
W.	Jan. 10, 1907	Tank effluent	2·0	·8	2·8	39	50	89	—	—	—	2·68	—	—	—	—	2·40	Sl. H_2S.
E. 296	Feb. 19, 1908	Tank effluent	2·0	4·0	6·0	24	43	67	—	—	—	1·40	—	—	—	—	1·32	No H_2S.
		MILL NO. 42.—BROWN PAPER.																
W. 104	Jan. 13, 1903	Crude liquids	76	96	172	64	112	176	·19	1·1	7·8	—	20·7	—	—	—	—	—
W. 105	Jan. 13, 1903	Tank effluent	6·0	22	28	58	100	158	·16	·84	2·7	—	7·5	—	—	—	—	—
W. 995	Jan. 17, 1905	Tank effluent	3·4	8·0	11·4	76	165	241	—	—	—	3·44	—	—	—	—	3·84	No H_2S.
W. 1220	July 6, 1905	Tank effluent	1·6	2·0	3·6	34	89	123	—	—	—	1·20	—	—	—	—	2·50	H_2S.
W. 1820	Nov. 8, 1906	Crude liquids	39	20	59	16	90	106	—	—	—	3·98	11·4	—	—	3·30	3·96	No H_2S.
W. 1821	Nov. 8, 1906	Tank effluent	2·0	4·8	6·8	48	137	185	—	—	—	2·30	7·0	—	—	6·98	2·46	No H_2S.
W. 1877	Dec. 10, 1906	Tank effluent	4·4	11·2	15·6	49	156	205	—	—	—	2·96	—	—	—	—	3·04	No H_2S.
W. 2396	Jan. 2, 1908	Tank effluent	3·2	1·2	4·4	48	131	179	—	—	—	2·46	—	—	—	—	2·02	No H_2S.
		MILL NO. 43.—BROWN PAPER.																
W. 106	Jan. 14, 1903	Crude liquids	135	155	290	172	305	477	·53	·76	23·6	—	39·6	—	—	—	—	—
W. 107	Jan. 14, 1903	Filter effluent	3·0	2·0	5·0	133	171	304	·31	1·17	7·4	—	18·1	—	—	—	—	—
W. 1524	May 6, 1906	Filter effluent	3·0	2·2	5·2	78	146	224	—	—	—	5·84	—	—	—	—	11·34	H_2S.
W. 1971	Feb. 21, 1097	Filter effluent	6·4	11·2	17·6	120	158	278	—	—	—	6·30	—	—	—	—	5·50	No H_2S
		MILL NO. 44.—BROWN PAPER.								Organic.								
L. 696	Dec. 7, 1904	Crude liquids	70·5	71·5	142	—	—	—	·80	5·23	—	11·32	33·4	—	6·9	20·8	11·4	H_2S.
L. 697	Dec. 7, 1904	Tank effluent	5·5	2·0	7·5	—	—	—	·18	1·42	—	2·12	6·0	—	—	—	3·08	H_2S.
L. 1991	Jan. 14, 1907	Tank effluent	2·0	·4	2·4	96	45	141	—	—	—	6·64	—	—	—	—	6·82	H_2S.
L. 2040	Feb. 6, 1907	Tank effluent	6·4	9·2	15·6	69	42	111	—	—	—	4·98	—	—	—	—	4·16	No H_2S.
L. 2526	Nov. 7, 1907	Tank effluent	2·8	2·0	4·8	59	60	119	—	—	—	4·60	—	—	—	—	5·96	H_2S.
L. 3188	Nov. 10, 1908	Tank effluent	2·0	1·2	3·2	46	66	112	—	—	—	2·54	—	—	—	—	2·64	No H_2S.
		MILL NO 45.—BROWN PAPER.								Albuminoid.								
W. 111	Jan. 16, 1903	Crude liquids	78	48	126	82	96	178	·35	·90	11·4	—	25·1	—	—	—	—	—
W. 112	Jan. 16, 1903	Tank effluent	7·0	2·0	9·0	76	92	168	·34	·83	7·0	—	14·0	—	—	—	—	—
W. 1696	Jan. 7, 1907	Tank effluent	4·2	3·8	8·0	48	93	141	—	—	—	3·18	—	—	—	—	3·20	H_2S.
W. 2027	April 10, 1907	Tank effluent	3·4	3·2	6·6	47	111	158	—	—	—	2·70	—	—	—	—	2·72	No H_2S.
W. 2664	July 8, 1908	Tank effluent	9·2	8·8	18·0	55	94	149	—	—	—	4·40	—	—	—	—	4·40	No H_2S.
W. 2848	Dec. 17, 1908	Tank effluent	3·2	2·8	6·0	66	141	207	—	—	—	4·38	—	—	—	—	4·42	No H_2S.

In the six foregoing crude liquids, the suspended solids varied from 35 to 135, the average being 84 parts per 100,000. In the twenty-one tank and filter effluents, the variation in suspended solids was from 2·4 to 28·0, the average figure being 8·9. The tank treatment had thus, on the whole, effected a very considerable reduction in the suspended matter. Neither crude liquors nor tank effluents developed sulphuretted hydrogen on incubation, although the figures for "Oxygen absorbed" from permanganate showed the presence of considerable oxidizable matter in the effluents, as discharged.

(4) *Wallpaper*

71. The materials used in this branch of paper-making consist of wood-pulp, rags and esparto.

The usual process of boiling with soda is followed, with evaporation for recovery of the soda from the boilings and the strongest wash waters.

In addition to the ordinary paper-making processes, wallpapers undergo printing and dyeing, and a large volume of coloured water results from the washing of dyebacks, colour vats, and printing rollers.

Various "thickening" substances are employed with the colours, as in the printing of cotton goods, and these thickening agents appear in the waste liquids, rendering them difficult of treatment.

The following analyses, handed in by Mr. E. Halliwell, show the nature of the liquids derived from a wallpaper mill, both before and after treatment; they refer to Mill No. 46 in the Ribble watershed.

Parts per 100,000.

Sample No.	Taken.		Suspended solids.			Dissolved solids.			Ammonia.			Oxygen absorbed.			In solution only.			After incubation.	
			Loss on Ignition.	Ash.	Total.	Loss on Ignition.	Ash.	Total.	Free.	Albuminoid.	Organic.	In 15 minutes.	In 3 minutes.	In 4 hours.	Albuminoid ammonia.	Oxygen absorbed.		Oxygen absorbed in 3 minutes.	Odour.
																In 3 minutes.	In 4 hours.		
	Mill No. 46.—Wallpaper.																		
W. 109	Jan. 15, 1903	Crude liquids -	73	112	185	106	199	305	·64	·69	—	16·8	—	27·8	—	—	—	—	—
W. 110	Jan. 15, 1903	Tank effluent -	1	2	3	46	100	146	·66	·27	—	4·0	—	6·4	—	—	—	—	—
H.	Sept. 17, 1906	Crude liquids -	31	17	48	28	58	86	·92	—	·92	—	2·48	7·52	—	—	—	—	—
H.	Sept. 17, 1906	Tank effluent -	3	2	5	37	97	134	·30	—	·60	—	2·04	6·52	—	—	—	—	—
W. 1974	Sept. 29, 1906	Tank effluent -	9	8	17	42	104	146	·57	·12	1·83	—	3·12	9·60	·10	—	8·52	2·92	No H_2S.
W. 1806	Nov. 6, 1906	Crude liquids -	56	53	109	58	112	170	—	—	—	—	4·72	14·6	—	2·44	9·96	5·04	No H_2S.
W. 1807	Nov. 6, 1906	Tank effluent -	3	10	13	42	127	169	—	—	—	—	2·16	8·04	—	2·12	7·56	2·20	No H_2S.

The settlement in this case was much the same as in the preceding one, the average figure for suspended solids in the three crude liquors being 114 and in the four tank effluents 9·4. Judged by the permanganate figures, these effluents are less polluting than the effluents from brown paper mills.

(5) *Cardboard.*

Mill No. 47.

72. The raw materials used in the manufacture of cardboard are "broken" paper, old magazines, paper bags, and occasionally string and rope.

The materials are soaked and pulped and then made into boards on a drum machine, a felt band being used instead of the woven wire band used in the ordinary paper-making machine.

The sheets, which vary from thin cardboard to boards ¼-inch in thickness, are removed from the machine in lengths of about 5 to 6 feet, and piled in a heap, each sheet being separated from its neighbours by cloths; they are then pressed in a hydraulic press and air-dried.

If the sheets are to be waterproofed they are specially treated and hung up in a chamber kept at a temperature of about 300° F.

Coloured boards are sometimes made, red oxide of iron being commonly used.

There is little waste liquor from any portion of the process, only about one third of the total water used being sent away as effluent, and most of this liquid having already been filtered through the felt band of the drum machine. Soda is rarely used (occasionally for string)—whilst the materials are sometimes boiled instead of being soaked.

The waste liquid is run into settling ponds worked in series, having a combined capacity of some 10,000 gallons.

The flow of waste liquor from this mill is about 1,500 to 2,000 gallons per 24 hours.

Summary as regards the Waste Liquors from Mills producing Brown Paper, Wall Paper and (possibly) Cardboard.

The waste liquor from these three classes of paper mills may be grouped together.

They are highly coloured, turbid, gummy, alkaline liquors. They contain much finely divided suspended matter, but the greater portion of the impurity is in solution.

The remarks made with reference to the liquors from esparto and rag mills as to the necessity for large scale experiments, apply here with even greater force.

We think that the evidence indicates that reduction of the suspended matter to 6 parts per 100,000 might be a reasonable requirement at the present time.

We have no analytical data relating to the waste liquors from mills where cardboard is manufactured.

SECTION III.

LIQUID WASTES WHICH ARE POLLUTING MAINLY BECAUSE OF THE DISSOLVED IMPURITIES WHICH THEY CONTAIN.

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73. Classification of liquid trade wastes under this head brings together a great variety of trades, all of which involve the use of water for washing dirty or greasy raw materials, for rinsing vessels which have contained soluble substances, as a diluent in chemical reactions or biological fermentations, or for gas purification, etc. It necessarily includes trades which have little or no connection with each other, and which give rise to wastes of very different kinds.

Strictly speaking, such trades should be dealt with separately, not only because the purification of the liquid wastes arising from them presents in most cases a special problem for investigation, but also because the waste liquids from a single trade frequently differ very considerably among themselves.

Any investigating authority should possess knowledge of the trade itself, and especially of the trade processes which involve the use of water. This is important in connection with all trades, but more especially in those which we are now considering, because in them purification of liquid waste may necessitate in the near future the the expenditure of considerable sums of money on the part of the manufacturers.

74. With the limited time available for our investigations in connection with the purification of liquid trade waste when unmixed with domestic sewage, it has been impossible for us to acquire knowledge of the kind referred to except in a few special cases. In our opinion the acquisition of this knowledge should be the duty of a permanent authority, who would be able to follow the development of each trade. In some cases trades undergo radical changes in the course of a few years, and these changes are at once evidenced in the character of the waste liquor discharged. It has, moreover, been clearly evident to us that manufacturing processes are tending to become more complicated, chemically and bacteriologically as well as mechanically, and that in the absence of systematic regulation waste liquors are likely to become a source of increasing pollution as time goes on.

75. In the case of distillery waste we thought it desirable to undertake a special investigation, for matters had become critical between the distillers and the riparian owners in the North of Scotland, and we were appealed to by the distillers. This work formed the subject of our Sixth Report. The adoption of our suggestions by certain distillers has been attended with satisfactory results as regards purification, but with the loss altogether of the valuable constituents of the pot-ale. This work should be followed up by experiments upon the utilisation of pot-ale.

76. We have also made some special experiments with regard to the purification of wool suds and of brewery waste, but with regard to other waste liquors—apart from some laboratory experiments—we have had to be content for the most part with the collection of information already in existence.

77. The wastes of this Section naturally fall into two broad divisions, namely: (1) Those which contain putrescible matter of organic origin, and (2) those which contain injurious chemicals.

The first division comprises such wastes as wool-scouring liquor, brewery waste, tannery waste, fellmongers' waste, dairy waste, silk-boiling waste, and liquors from glue, size and gut factories.

These wastes are all highly polluting in the same way that sewage is polluting—that is, they take up the dissolved oxygen from the river water into which they are discharged, and are liable to cause offensive putrefaction, to choke the bed of the stream with grease or other suspended matter, and to give rise to objectionable scum. On this account we think it may be necessary to demand from the great majority of traders producing this class of waste not only clarification, but oxidation and non-putrescibility.

78. The second division comprises spent gas liquor, shale oil waste, sulphite liquor from wood pulp paper mills, and drainings from chemical works or from chemical waste heaps.

These liquors also take up oxygen from water, but they do not directly set up putrefaction. On the contrary, they frequently delay it, and, being of a poisonous nature, they do injury to plants, fish, and in some cases to cattle.

It has been shown that this class of waste, or, at least, some varieties of it may be amenable to biological purification; but even in favourable circumstances the bacterial action is very slow. In some cases dilution with river water may—for practical purposes—be taken as merely weakening the action of such wastes without effecting true purification.

79. The purification of spent liquor from shale oil distillation on the large waste heaps which accumulate near these works is undoubtedly biological in part, and Dr. G. J. Fowler has shown that the spent liquor from gas works can, after dilution, be oxidized on artificial filters. The case of shale oil waste liquor is exceptional, however, for the heaps of hard spent shale are very large and the volume of waste liquor relatively small.

We are disposed to think that for other trades producing a similar kind of waste, biological purification may prove too costly for general adoption.

In our opinion, much more hope lies in the direction of preventing the formation of such liquors, or of largely diminishing their volume, so that they can be filtered through waste heaps or discharged into soak-away ponds and not sent direct into streams. It is interesting to note that a good deal has been done already in regard to diminishing the volume.

The disposal of these refractory trade wastes should be the subject of research by a permanent authority, for it is clear that in a number of cases practicable methods of purification are not yet available.

Waste Liquor from Wool-scouring.

80. Wool, as taken from sheep-skins or sheared from live sheep, is excessively greasy with dried perspiration, and has, besides, adhering to it more or less grass, seeds, dirt, and excrement. Practically all this has to be removed before the wool can be carded. The process of removal is termed wool-scouring, and it consists in passing the wool through a hot solution of soap and sometimes carbonate of soda, the mixture being kept agitated. The dirty solution, when run off, constitutes one of the most polluting of trade wastes.

As produced in large volume from the cleansing of raw wool, the suds contain, besides grit, etc., esters of cholesterin and allied bodies, probably free cholesterin, with oleic and other fatty acids, both free and combined as salts and esters; the nature of all the constituents is not yet fully known. In addition, there are also present considerable quantities of soluble organic nitrogenous matters and salts of potash; the suds we experimented with contained, on the average, about 300 parts of potash (K_2O) per 100,000 of suds.

Wool suds vary in quality, some being much more greasy and concentrated than others, according to the kind of wool that is being washed; Australian wool yields the most greasy suds. For present purposes, however, the waste may be regarded as a dirty, soapy emulsion, which varies considerably in strength.

At some wool-scouring works the greater part of the fat in this waste is recovered, but the recovery is incomplete. At one works the potash was also regained for a time; so long, that is, as very concentrated suds were being dealt with and the cost of evaporating the solvent water was not prohibitive.

Before proceeding to discuss the purification of wool-scouring liquor, we would refer shortly to an apparatus, for use in the de-greasing of raw wool, devised by Smith's Patent Vacuum Machine Company, Limited, Dewsbury, by means of which it is claimed that the potash, as well as the grease, can be profitably recovered. The process consists in treating the raw wool with petroleum naphtha under diminished pressure, and afterwards recovering the naptha from the grease solution by distillation. The de-greased wool is then extracted with a small quantity of water, which dissolves out the potash, the concentrated aqueous solution being afterwards evaporated and incinerated. The wool then requires very little further cleansing, so that the waste liquor produced is very small in amount.

Should this or any analogous process prove successful in practical working, but little waste liquor from wool, and that probably of a comparatively harmless nature, would be produced, a consummation much to be desired. But, in the meantime, it is necessary for us to consider the question of purifying the soapy waste liquors from wool-washing which are at present discharged in large volume, mainly in Yorkshire.

Many attempts have been made to recover the fat from wool suds at a profit, mostly by the use of solvents, and at the same time to effect a certain degree of purification. These have, however, usually proved too expensive. The method at present in use at most of the wool-scouring works in this country consists in "cracking" the wool suds, in tanks holding about 4,000 to 5,000 gallons each, with a slight excess of sulphuric acid (an excess amounting to about 100 to 200 parts of acid per 100,000 of suds), and allowing the fats to separate at the top and bottom of the tank. The acid liquor is then run off, either to the sewers or into a stream, as the case may be, while the crude fat magma is made into "puddings" in pieces of sacking and hot-pressed.

The character of the waste liquor arising from this process is seen from the following average figures of analysis from six chance samples from a wool-scouring works, which we examined in July and August, 1912.

WASTE LIQUOR, AFTER "CRACKING," AS RUNNING TO SEWER. PARTS PER 100,000.

	Minimum.	Maximum.	Average.	Number of estimations.
Total nitrogen (Kjeldahl) - - - - - -	17·9[*]	40·0	27·7	6
Oxygen absorbed from N/8 permanganate in 4 hours at 27° C. (80° F.) - - - - - -	133·1	254·6	186·6	5
Dissolved oxygen taken up from tap-water in 5 days 18° C. (65° F.) at - - - - - - - -	240·0	259·0	—	2
Total solids, dried at 105° C. - - - - -	915	1,786	1,362	6
Containing matter volatile on ignition - - -	321	803	540	6
Solids in suspension - - - - - - -	130	438	221	6
Containing matter volatile on ignition - - -	116	344	193	6
Fat - - - - - - - - - - -	120	342	191	6
Acidity, expressed as sulphuric acid, H_2SO_4 - -	46·2	158	89·2	6
Hardness,[†] expressed as carbonate of lime, $CaCO_3$ -	149	386	280	6

[*] The ammoniacal nitrogen in this was 7·05 and the organic nitrogen 10·85.

[†] This is "permanent" hardness, due to sulphates of lime and magnesia.

That such a liquor is highly polluting, many times as polluting as an ordinary sewage—is obvious at a glance. It is, too, distinctly acid and very hard, and it still contains much fat.

It has been suggested to us that this liquor might be precipitated with a small quantity of alumino-ferric plus a large quantity of lime, followed by continuous flow settlement. This would entail only a comparatively small capital expenditure for additional tanks to those already existing at wool-scouring works. The sludge could be cracked with vitriol, the resulting magma hot-pressed, and the "acid recovery liquor" used over again.

We have no data to show whether the value of the grease recovered in this way would compensate for the extra chemicals used in the precipitation of the "cracked" liquor and the subsequent "cracking" of the second magma, but we doubt whether it would do so. The clarified liquor produced would still be very polluting and in some cases likely to be objectionable on account of its extreme hardness.

Of recent investigations bearing upon the purification and utilization of wool suds, we may refer to the following:

A report by Mr. H. W. Clark to the Massachusetts State Board of Health, published in 1910, gives the results of a number of small-scale experiments made by him on the waste liquors from scouring and washing wool. He deals successively with (*a*) filtration of these through sand filters, (*b*) sedimentation, (*c*) chemical precipitation, etc. In the precipitation experiments he found calcium chloride to be more efficient than anything else tried. In the filtration experiments through sand filters he obtained the best results with wool suds which had been allowed to become septic.

In April, 1911, Dr. Maclean Wilson presented a report to the West Riding of Yorkshire Rivers Board on the "Treatment of Wool-washing Refuse." He says (p. 3):—

> "This process (*i.e.*, the present process of 'cracking') is incapable of producing a satisfactory effluent. At the best, the effluent will be a strongly acid liquor, for, as is evident from the analyses, a considerable excess of acid is required to separate the grease thoroughly. It is also highly charged with dissolved organic matters, which are very putrescible immediately the excess of acid is neutralised."

After testing experimentally the effect of various precipitants on the liquid resulting from "cracking," and finding that the best results were obtained by using lime to neutralise the acidity, and then adding a further quantity along with ferric sulphate to precipitate the organic matters, he discussed the possibility of direct precipitation of the untreated suds on the lines adopted for piece-scouring liquor at Mill No. 23 (*cf.* p. 65). Finally, he passed some of the precipitation liquor through a small biological filter in the laboratory, and obtained a non-putrescent effluent.

Following on this work of Dr. Wilson, Dr. G. J. Fowler, at the instance of the West Riding Rivers Board, carried out in 1911 a further laboratory investigation on the composition and possible methods of purifying the liquid refuse from the process of wool-scouring, as carried on in the West Riding. After analysing some typical samples of treated (*i.e.*, cracked with acid) and untreated suds, he studied the effect of various precipitants on these, and also the effect of biological filtration on the precipitated liquors. The greater part of the investigation was, however, confined to the precipitation of the liquor after cracking.

In his report to the Board, he says:

> "It is very evident that the present process is not carried out in such a manner as to effect a perfect separation of the grease; some of the samples were not even properly cracked. Apart from the grease, much oxidizable matter of a putrefactive nature is present in solution."

Like Dr. Wilson, Dr. Fowler obtained good clarification by precipitating the liquor resulting from cracking with a mixture of lime and either ferric or aluminic sulphate. He then went on to the direct precipitation of the untreated suds on the lines adopted at Mill No. 23. Finally, he filtered small portions of the precipitation liquor through matured laboratory biological filters of fine material, and says:

> "It may safely be concluded that the clarified liquors are amenable to biological filtration, though the process is somewhat slow. . . ."

The various experiments, which have just been briefly referred to, indicated that the purification of wool suds by direct precipitation would in all probability be successful on a large scale if the process were carried out with reasonable care.

So far back as 1908, we had desired to ascertain whether wool suds might be amenable to direct precipitation, without previous cracking, one object being to avoid the production of a very hard precipitation liquor.

We, therefore, decided to have some precipitation experiments made in the laboratory, and, if these were encouraging, to undertake some further precipitation (and possibly filtration) experiments on a larger scale out of doors.

The laboratory experiments were carried out at Ealing, in the summer and autumn of 1911, on various samples of wool suds received from Woolcombers, Limited, Bradford.

The precipitants used were:

1. Alumino-ferric.
2. Alumino-ferric and lime.
3. Alumino-ferric, lime and sulphuric acid.
4. Calcium chloride.
5. Calcium chloride and lime.
6. Ferrous sulphate (copperas).
7. Precipitant "X" (partially oxidized copperas).
8. Precipitant "X" and lime.
9. Ferric chloride.
10. Ferric chloride and lime.
11. Ferric sulphate.

It is unnecessary to give the results of these experiments in detail; they were summarised in a short report presented to us by Dr. McGowan and Mr. Frye in November, 1911. Suffice it to say that the best precipitation results were obtained by using ferric salt alone, in slight excess (in the proportion of about 300 to 370 parts ferric chloride or sulphate to 100,000 of suds containing about 1,000 parts of fat), the fat in the precipitation liquor being reduced to about 1 per cent. of that in the original suds. The precipitation liquor, whatever the precipitant used, was always highly polluting; it was also very hard, excepting when ferric salt alone was employed.

The experiments carried out by Drs. Fowler and Wilson, separately, on the neutralised liquors from cracked wool suds, showed clearly that such liquors could be purified by biological filtration. We have ourselves found the precipitation liquor from wool suds—whether obtained by cracking with acid or by precipitation without cracking—to take up dissolved oxygen from water readily. Further, some laboratory filtration experiments, using a small filter of matured clinker, have shown the liquor obtained from wool suds by direct precipitation to be amenable to bacterial filtration, so as to yield a non-putrescent effluent (*Cf.* Appendix, No. 3, note by Dr. McGowan).

As already mentioned, the precipitation liquor from direct precipitation is still very impure, containing as it does much ammonia and organic nitrogen and much oxidizable carbonaceous matter; it is, however, not excessively hard. If such a liquor had to be purified on a working scale upon biological filters, it would probably be well to run it in the first instance through a second tank, adding to it on its entrance a small quantity of milk of lime. This would help to bring down any traces of iron still in solution, and also any particles of floating matter, and would thus be a preventive against clogging of the filter material.

Laboratory experiments were also made on the "cracking" of the magma deposited in the precipitation, and further experiments, on a somewhat larger scale, were carried out at the engineering works of Messrs S. H. Johnson & Co., Stratford, E. These latter consisted in the precipitation of about 30 litres of wool suds at a time, cracking of the magma, and subsequently pressing in a very small steam-jacketed press, the main object being to find out whether the sludge produced by cracking the magma with a slight excess of acid could be readily pressed.

Our laboratory experiments on the direct precipitation of wool suds having answered expectation, we decided to investigate the subject further by out-of-doors experiments on a fairly large scale. Through the courtesy of The Woolcombers, Limited, we were enabled to do this at Mill No. 48, in Bradford, and we desire to express our thanks for the facilities afforded to us.

Mr. A. C. Carter, assistant chemist to the Commission, acting in conjunction with our senior officers, was placed in direct charge of the experiments; he superintended all the operations and drew samples for examination at Ealing. For the full details of these large-scale experiments the reader is referred to the report by Mr. Carter, given in the Appendix, No. 2, but some of the more important points may be considered here.

Scale on which the Precipitation Experiments at Mill No. 48 *were conducted.*

With the exception of the first, in which 3,000 gallons of wool suds were used, 2,000 gallons were taken for each experiment. After some preliminary trials, a set of five experiments (of 2,000 gallons each) was made, and on the results of these the main conclusions of this section of the report are based.

The average composition of the wool suds experimented with is shown in the following table, the figures in brackets giving the number of samples tested.

CRUDE WOOL SUDS AFTER GRIT SETTLEMENT.

	Parts per 100,000.		
	Minimum.	Maximum.	Average.
Total nitrogen (Kjeldahl)	18·6	60·8	46·0 (10)
Oxygen absorbed from N/8 permanganate in 4 hours at 27° C. (80° F.)	397·7	617·4	494·1 (10)
Dissolved oxygen taken up from tap-water in 5 days at 18° C. (65° F.)	360·0	542·0	429·0 (5)
Total solids, dried at 105° C.	1,792	3,029	2,406 (10)
Containing matter volatile on ignition	1,036	1,797	1,448 (10)
Fat* (*i.e.*, matter extracted by ether and afterwards volatile on ignition)	574	1,192	912 (10)
Alkalinity (expressed as H_2SO_4) :—			
(*a*) due to alkali soluble in water	303	477	363 (9)
(*b*) due to carbonates insoluble in water	122	210	137 (9)

* Estimated by "cracking" the suds with dilute sulphuric acid, filtering, washing, drying *in vacuo* and extracting with ether.

The solids in suspension consisted mainly of fat, and it was practically impossible to determine them accurately by the ordinary method of filtration through asbestos in a Gooch crucible.

The precipitants used in the experiments were Pochin's liquid ferric sulphate, at 27*s.* per ton, and Spence's M/L sewage cake, at 32*s.* per ton. These gave the following analyses :—

Parts per cent. by weight.

—	Pochin's liquid ferric sulphate (Sp. Gr. = 1·33).	Spence's M/L sewage cake.
Total iron as ferric oxide plus alumina	9·36	16·83
Ferric oxide (Fe_2O_3)	5·23	3·35
Ferrous oxide (expressed as Fe_2O_3)	0·48	1·13
Alumina, Al_2O_3 (by difference)	3·65	12·35

The process was as follows :—

(1) Precipitation of wool suds, using a certain quantity of fresh precipitant, together with the "acid recovery liquor" obtained from "cracking" the precipitate of the previous operation; mixture was promoted by blowing in air and a little steam.

(2) Settlement of the precipitate. A settlement of 16 to 20 hours was found to give the best results.

(3) Drawing off the precipitation liquor (usually about half the total content) by means of a floating arm.

(4) Cracking the precipitate with vitriol.

(5) Settlement of the magma; this took 10 to 15 hours, but it might be expedited on the large scale by a special arrangement of tanks.

(6) Drawing off the "acid recovery liquor."

(7) Hot-pressing the magma for grease and for additional recovery liquor.

The precipitation liquors produced were alkaline in reaction, brownish, and slightly turbid, but, practically speaking, they were almost free from suspended solids and from fat. They gave the following figures on analysis :—

Precipitation Liquors.

Average figures of Analysis.

There were two samples in the first series of experiments, two in the second, and four in the third.

Parts per 100,000.	Series I., using Pochin's ferric sulphate.	Series II., using Pochin's ferric sulphate + lime.	Series III., using Spence's M/L sewage cake.
Ammoniacal nitrogen	8·5	—	—
Albuminoid nitrogen	3·0	—	—
Total nitrogen (Kjeldahl)	13·7	18·8	25·6
Oxygen absorbed from N/8 permanganate in 4 hours at 27° C. (80° F.)	54·1	100·5	64·2
Dissolved oxygen taken up from tap water in 5 days at 18° C. (65° F.)	20·1	More than 48·0	58·9
Total solids	1,084	1,230	1,262
Volatile matter in these solids	179	306	261
Solids in suspension*	3·5†	—	—
Fat	—	—	5·0
‡Hardness (expressed as $CaCO_3$)	186·5	152·9	256·2
Ferric oxide (Fe_2O_3) + Alumina (Al_2O_3)	69·9	5·0 (all alumina)	53·7

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* The samples of precipitation liquor contained so little suspended matter (comparatively speaking) that it was not thought necessary to continue estimating it. It would be safe to say that the amount was always under 4 to 5 parts per 100,000.

† One estimation.

‡ This is the total hardness, mainly permanent.

Table XI. in the Appendix (No. 2), gives in detail the main inorganic constituents of the ten samples of precipation liquor of Experiments I., II., and III. Of the bases present, the potash constituted more than half of the whole and the soda about one quarter, the remainder consisting of iron, alumina, lime, and magnesia.

The grease recovered, taking all the experiments, averaged 61 per cent. of the grease in the original suds. The press used was, however, not of a modern type and there can be no doubt that a better yield than this could be obtained in practice. The pressed cake contained, on the average, 27·8 per cent. of its weight of grease.

The question of the tank capacity requisite for the proper working of the above process, as outlined, is very important. We are advised by our officers that, for a daily flow of 80,000 gallons of wool suds, a total tank capacity (including settling, cracking, and acid recovery tanks) of 185,000 gallons would be amply sufficient.

Calculations of Cost of Precipitation.

The problem of precipitating wool suds on a practical scale is thus reduced mainly to a question of cost.

The figures most to be relied upon, when speaking of costs, are those of Experiment III., which was made with Spence's M/L sewage cake. This series comprises five successive precipitations, and the average results should therefore give figures of costs approximating to the truth.

By referring to Table IX. in the Appendix (No. 2), it will be noted that in Experiment F, the first of the series, the weight of M/L precipitant added was 240 lbs., as against an average weight of 105 lbs. for each of the succeeding four experiments, 2,000 gallons of suds being used for each precipitation. This difference is, of course, due to the recovery and the use again of the precipitant in the acid liquor obtained by cracking the magma with sulphuric acid. For this reason the figures given for the cost of the precipitant used leave the first precipitation out of account.

The average quantity of M/L sewage cake required for 2,000 gallons of suds at Mill No. 48 may thus be taken at 100 lbs. At 32*s*. 6*d*. per ton (loose in trucks at Bradford), the price quoted by Messrs. Spence & Sons, this represents a figure of £18 4*s*. per week on a total flow of 500,000 gallons of suds, which, we were informed, was the weekly discharge from the works.

In this series of precipitations no lime was used in addition to the M/L sewage cake. The precipitation liquor, however, contained on an average something like 55 parts per 100,000 of oxides of iron and aluminium, and this might have to be removed in practical working by the addition of lime. There are not sufficient data to allow of an exact estimate of the amount of lime to be added here, but 50 lbs. per 2,000 gallons of suds would be a generous allowance.

Taking the price of lime delivered at Bradford at 15*s*. per ton, this would represent an additional cost of £4 4*s*. per week.

The average quantity of sulphuric acid (Sp. Gr. 1·60) * used for cracking the precipitate may be taken at 100 lbs. per 2,000 gallons of suds. At £1 15*s*. 8*d*. per ton this amounts to £19 19*s*. 6*d*. per week.

The total cost of precipitating and cracking 500,000 gallons of suds per week would therefore be

	£	*s*.	*d*.
M/L sewage cake - - - - - -	18	4	0
Lime - - - - - - - -	4	4	0
Sulphuric acid - - - - - -	19	19	6
	£42	7	6

The variation in the quality of the wool suds at Mill No. 48 has already been remarked upon. On account of this variability it is not possible to arrive with precision at the quantity of grease which would be produced per week by the above process of direct precipitation.

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* This represents 70 per cent. sulphuric acid.

Taking, however, all the ten samples of wool suds examined over a period of six weeks, the average quantity of grease found was 912 parts per 100,000 (lowest, 574; highest 1,192).* If we take the average at 900 parts (the figure arrived at in Experiment 3), this represents 20 tons of grease per week.

The average quantity of grease recovered by cracking and pressing in Experiment 3 was 61 per cent. of the total grease contained in the suds. For the purpose of calculation it may be taken as 60 per cent., which is equivalent to an output of pressed grease of about 12 tons per week (*Cf.* Appendix. (No. 2), Table VIII).

The price of wool grease in November, 1912 varied from £9 10*s.* to £10 per ton. Taking the lower figure, the value of grease produced per week would amount to £114.

The cake which results from the pressing of the acid magma is also of value. It has been sold at prices varying from 3*s.* 6*d.* to 7*s.* 6*d.* per ton. The total production would approximate to 30 tons per week.

Taking the average price at 5*s.* per ton, this would amount to a weekly sum of £7 10*s.*

The grease and cake together would thus represent a total income of £121 10*s.* per week.

It has been contended that the pressing of acid magma involves an excessive cost in press cloths, owing to the corrosive action of the acid. But this is not the case. Messrs. John Foster & Sons, Limited, of Queensbury, who have for some years past used a filter-press for the removal of grease from acid magma, give the average cost in filter press-cloths per ton of grease produced as 5*s.* 1*d.* Messrs. Hill & Sons, of Batley Carr, have given the cost of the same item as 4*s.* 8*d.* † per ton of grease.

As regards labour, it is estimated that, working day and night, a total staff of 6 men (4 day men and 2 night men), together with a foreman, would be necessary to work the plant efficiently. At 24*s.* for day men, 25*s.* for night men, and 32*s.* for the foreman, this would amount to £8 18*s.* per week.

The following statement gives the cost of precipitants, filter-press cloths and labour, alongside of the total income from grease and cake.

It should be noted that neither the cost of steam power nor the expenses incidental to this, *e.g.*, lubricating oil, etc., are included.

Dr.	£	*s.*	*d.*	*Cr.*	£	*s.*	*d.*
12 tons of grease at £9 10s.	114	0	0	11·2 tons M/L sewage cake at 32s. 6d.	18	4	0
30 tons of cake at 5s.	7	10	0	5·6 tons lime at 15s.	4	4	0
				11·2 tons sulphuric acid at £1 15s. 8d.	19	19	6
				Press cloths	3	1	0
				Labour	8	18	0
	£121	10	0		£54	6	6

Capital Outlay.

The capital cost of the precipitation and settling tanks would vary very considerably, according to the circumstances obtaining at each mill or works. For this reason only a general idea of capital cost based on normal conditions can be given here.

Our Engineer, Mr. G. B. Kershaw, estimates that the cost of the tank installation, as suggested (including six precipitation tanks, two Dortmund tanks, and five acid-resisting tanks), would approximate to £1,500 under average conditions.

Probably five large filter presses (each press 3 feet square and comprising 60 chambers) would be required. The cost of these presses would be about £300 each, or a total of £1,500. Something like 10 per cent. depreciation would have to be allowed on the presses, owing to the use of acid liquor.

To work the presses an air-compression plant including a 30 h.p. engine would be required. The total cost of this would be about £350. In this case, also, a depreciation of 10 per cent. should be allowed.

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* Note.—In order to gain further information with regard to the amount of fat present in the wool suds at Mill No. 48, 14 further samples, extending over a period of a month, were drawn and examined in January and February, 1913. Each of them was made up of 23 sub-samples, drawn hourly throughout the day. The fat in these average samples ranged from 720 to 1,775 parts per 100,000, the average for the whole being 1,095 parts. The detailed figures of analysis, together with the amount of ferric salt required by each sample for complete precipitation in the laboratory, are to be found in the Appendix (No. 2), Table XI. The amount of precipitant required was approximately proportional to the amount of fat present.

† Average for 5 years.

The total capital outlay would thus be somewhat as follows:—

	£
Tanks	1,500
Presses	1,500
Air-compression plant	350
	£3,350

Allowing 3½ per cent. depreciation on the tanks and 10 per cent. on the machinery, an annual charge for depreciation of £237 10*s.* is arrived at. Allowing 5 per cent. interest on capital expenditure for the plant alone, *i.e.*, excluding the cost of land, there would be a further annual charge under this head of £167 10*s.*

Taking the estimated figures of cost for barrels, repairs, gas, sundries, supervision, rent, rates and steam, supplied to us by Woolcombers, Limited, as relating to Mill No. 48, we arrive at the following statement of estimated receipts and expenditure:—

	£	*s.*	*d.*	£	*s.*	*d.*
Debit.						
Chemicals	2,120	0	0			
Press cloths	152	10	0			
Barrels (at 23s. a ton)	690	0	0			
Repairs and renewals	106	0	0			
Gas	46	0	0			
Sundries	12	0	0			
Wages:						
1 Foreman at 32s.	462	16	0			
4 day men at 24s.						
2 night men at 25s.						
Supervision	50	0	0			
Rent	25	0	0			
Rates	67	0	0			
Interest on Capital (5 per cent. on £3,350)	167	10	0			
Depreciation (tanks 3½ per cent., machinery 10 per cent.)	237	10	0			
Steam at 10s. per ton of grease—600 tons	300	0	0			
				4,436	6	0
Credit.						
600 tons grease at £8	4,800	0	0			
1,500 tons sudcake at 3s.	225	0	0			
				5,025	0	0
Profit				£588	14	0
or						
600 tons grease at £10	6,000	0	0			
1,500 tons sudcake at 6s.	450	0	0			
				6,450	0	0
Profit				£2,013	14	0

It should be borne in mind that the foregoing costs have been based on experiments conducted with an old type of press. By using a modern pressing plant, the yield of grease would certainly be increased.

It is also important to point out that the profit obtained from this treatment of wool suds depends mainly upon the amount of grease contained in them. If weaker suds were to be dealt with, the cost of treatment would diminish, but not to the same extent as the returns from the grease.

Assuming, for instance, that the average quantity of grease in the suds fell to 600 parts per 100,000, as against the 900 parts per 100,000 taken in the calculations, the total return for grease would be reduced from £6,000 to £4,000 (£2,000); whereas the cost of treatment would probably be only reduced by about £700.

From the foregoing calculations of cost we feel satisfied that, even allowing for the fact that estimates of profit are more often than not too sanguine, the suggested precipitation process for the treatment of wool suds could in all probability be worked with a considerable margin of profit.

It is only fair to add, however, that this conclusion as regards yield of grease and cost has not been accepted by Woolcombers, Limited.

Summary as regards Wool Scouring.

From most works the waste liquors from wool scouring pass into sewers, but in a number of cases they are discharged direct into streams, giving rise to serious pollution. We have endeavoured to show that there should be no serious difficulty, either as regards procedure or cost, in so precipitating the waste as to render it practically free from fatty matter, recovering at the same time the greater part of the fat.

The precipitation liquor, though well clarified, is still very impure, containing much nitrogenous and other organic matter (derived partly from fæcal matter originally adhering to the fleeces), and it readily takes up dissolved oxygen from water and becomes putrescent. Wherever possible, therefore, such clarified liquor should be discharged into sewers.

Nevertheless this clarified precipitation liquor should, we think, be regarded as something very different from the greasy liquor at present being discharged from most works after simple cracking of the suds with acid. It is practically free from fat and other suspended solids, and cannot, therefore, foul the bed and sides of a stream to anything like the same extent as the latter. Nevertheless, as a river polluting agent, it must needs be regarded in the same light as a concentrated sewage liquor, which therefore requires oxidation, in addition to clarification, if it is to be discharged direct to a stream. It is, however, necessary to add that the practicability of purifying this liquor on a large scale by biological filtration has not yet been demonstrated.

Mention may, however, be made of experiments carried out in the laboratory on the biological filtration of the precipitation liquor through a small filter of matured clinker, 3 feet 8 inches long and 2½ inches internal diameter, which gave good results, thus :

Precipitation liquor, 2E, was filtered for three days at the rate of 25·3 gallons per cube yard per 24 hours. The figures of analysis of the liquor and the effluent were as follows :—

Parts per 100,000.	Precipitation Liquor. 2 E.	Filter Effluent.
Ammoniacal nitrogen - - - - - - -	—	0·2 approx.
Nitric nitrogen - - - - - - - -	—	1·2 approx.
" Oxygen absorbed " from N/8 permanganate at 27° C.—		
At once - - - - - - - -	38·8	8·8
In 4 hours - - - - - - - -	122·4	29·7
Dissolved oxygen taken up from tap water at 18° C. in 5 days - - - - - - - -	—	4·5
Incubator test - - - - - - - -	—	Passed.

As calculated on the " oxygen absorbed " in 4 hours, the purification amounted to 76 per cent., and the actual oxidation effected was quite comparable with that done in the percolating filtration of sewage liquors.

The filtrate was a frothy liquor of brown colour, with a somewhat musty odour.

A second filtration of the effluent, at the same rate, only reduced the 4 hours' figure to 25·0.

A third filtration, at a rather quicker rate, only reduced the 4 hours' figure to 18·6.[1]

A fourth filtration, at a rather slower rate, only reduced the 4 hours' figure to 19·2.[2]

From these figures for " oxygen absorbed " from permanganate, and dissolved oxygen taken up from water, it is evident that this filtrate contained some very resistant organic matter. Even the addition of sewage liquor to it and further filtration of this mixture did not greatly reduce the 4 hours' figure.

While the experiments quoted are far from being exhaustive, they indicate that the direct precipitation liquor from wool suds is amenable to biological filtration at a reasonable rate, so as to yield a non-putrescent effluent. Having regard to these results, and at the same time bearing in mind the organic " strength " of the original liquor, we think that—assuming that the laboratory experiments are confirmed by results in practice—a reasonable requirement at present for this class of effluent would be 4 parts of suspended solids and 4 parts dissolved oxygen absorption in 5 days per 100,000.

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1 and 2. These estimations done on paper-filtered and settled examples, respectively.

It is well to point out that whatever process of purifying wool suds be adopted spores of anthrax may be present in the effluent and more especially in the resulting sludges. The discharge of such effluents into streams or the application of such sludges to the land as manure is therefore not unattended with danger to animals drinking from the stream or grazing on the land.

In conclusion, apart from the question of stream pollution, we would desire to emphasize the point that, while purification of wool suds by precipitation, as outlined, allows of the recovery of the fat, much valuable material, more especially potash and nitrogen, is lost. It is therefore, to be hoped that methods will soon be available by which not merely the raw wool can be purified, but also all its useful by-products saved.

Brewery Waste.

81. For the process of brewing, barley is first converted into malt by steeping it in successive portions of water, and, after the "steep water" has been run off, spreading it out to germinate and then drying. The malt, after being crushed, is digested with warm water, the aqueous solution, termed the "wort," being then separated from the solid residue of spent "grains." In this process of digestion the starch present in the malt is converted, through the agency of a group of ferments called diastase, into dextrin, maltose, etc., *i.e.*, speaking generally, into sugar. The wort is next boiled, with the addition of hops, and the solution run off and cooled. It is finally fermented with yeast, *i.e.*, the sugar present is transformed into alcohol and carbonic acid, the resulting beer being then run into casks.

The waste liquids from a brewery consist of cask washings; washings from the brewing vessels, fermentation squares, yeast backs and floors; bottle washings; square water; and (in the malting season) steep water. The cask washings and steep water together make up about two-thirds of the whole volume of waste liquor.

Brewery waste contains organic matters of various kinds, both in suspension and in solution, and constitutes a very polluting mixture. Apart from pieces of cork and other coarse matters, the suspended solids are largely made up of spent yeast and hops. The matters in solution are relatively carbonaceous, though nitrogenous compounds are also present in quantity.

Brewery waste, if left to itself, quickly undergoes acid fermentation, with subsequent liberation of sulphuretted hydrogen. Since its temperature when discharged from a brewery is usually high, this tends to quicken its decomposition and to accentuate the smell. It is, therefore, important to keep such waste, whether unmixed or mixed with sewage, alkaline.

Difficulties have arisen on sewage farms from the acid fermentation of sewage containing much brewery waste. The most notable instance was that of Burton-on-Trent some twenty years ago, where at the time the sewage consisted of about 1 volume of domestic sewage and 3 volumes of brewery waste, and where the decomposition of the yeast and hop leaves, etc. deposited on the land, resulted in the production of much sulphuretted hydrogen and in a consequent nuisance from smell. Further, this mixture of sewage and brewery waste might vary in temperature as much as 35° or 40° F. in the course of the day. After a number of attempts had been made to abate the nuisance, the difficulty was overcome by Professor (now Sir James) Dewar, who recommended the addition of 40 to 50 grains of lime per gallon of sewage, before allowing it to pass on to the land. We are informed that with careful and unintermitting attention this method works satisfactorily.

Stratford-on-Avon may also be cited, the sewage there containing about 40 per cent. of brewery waste in the warmer months. This sewage is successfully treated by septic tanks, percolation filters, and (a small area of) land, an excellent effluent being produced. There was, however, a strong and unpleasant odour from the septic tanks, which had to be overcome by the addition to the issuing tank liquor of some lime or hypochlorite, or both.

Many town sewages contain more or less brewery waste, but experience has shown that the presence of this waste—unless in preponderating amount, as at Burton-on-Trent—need not interfere materially with the purification of the sewage either on biological filters or on land, given sufficient filtering area.

Where, therefore, brewery waste can have access to the sewers of a town, we consider that it should be received into those sewers and treated with the sewage (*Cf.* our Third Report, pp. 17–20). It is unnecessary to mention further cases where this is being done, since they are to be found all over the country.

The discharge of waste from breweries in country districts where there are no sewers has given rise to numerous cases of pollution of rivers, but this ought no longer to occur, as the waste is amenable to purification through biological filters as well as through land.

Treatment of Brewery Waste on Percolation Filters.

Through the courtesy of the proprietors of Brewery No. 49, we were enabled to keep the purification plant there under the observation of our Officers, Mr. E. H. Richards, until recently our senior assistant chemist, being stationed at the brewery during two periods of three weeks and a fortnight, respectively, to observe the working of the plant and to collect samples for examination at Ealing.

Mr. Richard's report is given in the Appendix (No. 3).

All the waste liquors from the brewery were formerly discharged untreated into a small brook, which became in consequence so polluted that a purification plant was installed in 1904. As will be seen from what follows, this plant has given satisfactory results.

The total volume of waste liquor treated per day was, during the periods of observation, from 2,000 to 3,000 gallons. It consisted mainly of cask washings, steep water (in the malting season) and "square" water, but included also the various wash waters of the brewery.

The combined liquors flow into a septic tank, together with a very small volume—about 30 gallons per day—of the brewery sewage and slop water. This tank has a capacity of 17,625 gallons and is divided longitudinally into two sections; it is covered by loose corrugated iron plates. The tank is usually run for about a year without cleaning, when the sludge, mixed with ashes, is put on to the land.

The tank liquor is filtered through two percolating filters of coarse clinker, having a total capacity of 418 cube yards, being discharged intermittently on to the filters by revolving sprinklers. Throughout the observations the tank liquor was always alkaline in reaction.

The composition of (*a*) the brewery waste alone, not including steep water, (*b*) the mixed brewery waste and sewage, (*c*) the septic tank liquor, and (*d*) the filter effluent, is seen from the following figures in Table I, obtained by the analysis of six approximately average samples of each*, drawn half-hourly over six days in March and April, 1911. Table II contains similar figures from the analysis of four chance samples and four average samples each of septic tank liquor and filter effluent, drawn in January and February, 1912. During the first period steep water was not being treated, but during the second it was.

TABLE I.

Parts per 100,000.	Brewery waste.	Mixed brewery waste and sewage.	Septic tank liquor.	Filter effluent.
Ammoniacal nitrogen	0·18	1·47	6·34	0·15
Albuminoid nitrogen	2·96	3·06	1·15	0·07
Total organic nitrogen	6·60	6·41	2·04 (5)	—
Nitrous nitrogen	—	—	—	0·04
Nitric nitrogen	—	—	—	1·51
Total nitrogen (Kjeldahl)	6·78	7·88	8·27 (5)	2·13
Oxygen absorbed from N/8 permanganate at 27° C. *at once*	6·26	5·73	2·58	0·25
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	79·2	57·4	10·37	0·75
Dissolved oxygen taken up from tap water at 18° C. *in 48 hours*	94·2 (5)	67·3 (3)	28·1	0·42
Dissolved oxygen taken up from water at 18° C. *in 5 days*	146·4 (5)	135·1	51·1	0·70
Incubator test (by smell)	—	—	—	All passed
Chlorine	2·74	2·52	2·93	1·87
Solids in suspension	88·3	61·9	24·3	2·8
Containing matter volatile on ignition	77·6	54·0	19·5	1·4
Total hardness, by soap test, expressed as carbonate of lime ($CaCO_3$)	—	—	—	27·2
Permanent hardness (as $CaCO_3$)	—	—	—	10·9

* NOTE.—Excepting in a few instances, where the number of estimations is given by a figure in brackets.

TABLE II.

Parts per 100,000.	Chance Samples.		Average Samples.	
	Septic tank liquor.	Filter effluent.	Septic tank liquor.	Filter effluent.
Ammoniacal nitrogen	3·17	0·07	2·22	0·02
Albuminoid nitrogen	1·00	0·12	1·02	0·09
Total organic nitrogen	1·73	?	1·87	0·16 (2)
Nitrous nitrogen	—	trace	—	0·00
Nitric nitrogen	—	1·52	—	1·45
Total nitrogen (Kjeldahl)	4·89	1·66	4·09	1·50
Oxygen absorbed from N/8 permanganate at 27° C. *at once*	4·22	0·27	4·80	0·20
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	16·23	1·05	17·75	0·84
Dissolved oxygen taken up from tap water at 18° C. *in 48 hours*	68·7	0·27 (3)	75·9	0·36 (3)
Dissolved oxygen taken up from water at 18° C. *in 5 days*	100·2	0·87	115·4	0·81
Incubator test (by smell)	—	All passed	—	All passed
Chlorine	5·17	3·33	5·62	5·00
Solids in suspension	10·7	3·6	8·5	1·0
Containing matter volatile on ignition	8·1	1·8	7·1	0·6

The figures in Table I. shew that the brewery waste was mainly carbonaceous in character and that it took up oxygen readily from water; the addition of the small quantity of sewage rendered it slightly more nitrogenous. It is further seen from both tables that the long stay of the liquor in the septic tank had the effect of converting most of the organic nitrogen compounds into ammonia, the tank liquor, especially when steep water was present, being still capable of taking up much oxygen. The filter effluents were throughout of excellent quality.*

There was no smell of any consequence from the (covered) septic tank itself; the offensive odour which arose from the splashing of the pulsometer could easily be rectified.

The data available do not allow of saying with certainty whether the continuous addition of a small proportion of sewage to brewery waste is essential, after maturing of the septic tank has once taken place. The results do show, however, that the brewery waste liquor in question, mixed with a very small proportion of sewage, yields—at least after a prolonged stay in the tank—a septic tank liquor capable of being readily purified by biological filtration.

The strength (†) of this brewery waste, at the time when it contained no steep liquor, was about three times that of an average sewage, and the strength of the septic tank liquor about one-and-a-half times. In the waste itself the amount of very readily oxidizable matter was relatively low, while in the septic tank liquor it was relatively much the same as in a septic tank liquor derived from domestic sewage.

It is probably safe to infer that the rate of filtration, through a percolating filter of coarse material, of such a septic tank liquor from brewery waste, whether containing steep water or not, should be about the same as for a sewage of equal strength. The filter might thus reasonably be called upon to treat about 40 to 50 gallons of such a septic tank liquor per cube yard per 24 hours and produce a good well oxidized effluent (‡). At this rate, however, it is probable that either more organic solids would accumulate in the filter or would be washed out in the effluent than was the case during our observations, when the filters were only treating at the rate of 42 gallons per cube yard per 24 hours, during 3½ hours of the day, and resting for the remaining 20½ hours.

Treatment of Brewery waste upon contact beds.

We have not made systematic observations upon this method of treatment, but our officers visited the following three breweries where it is carried out and took samples for chemical examination.

Brewery No. 50.

This plant receives a daily flow of 40,000 gallons, consisting of about 5,000 gallons of domestic sewage and 35,000 gallons of brewery waste.

The sewage flows through a screen and through a grit chamber into a covered septic tank, 42 feet long, 20 feet wide by 8 feet deep, holding 40,000 gallons. From this tank the liquor flows into a dosing tank holding 10,000 gallons, whence it is automatically discharged on to four primary contact beds, each of which are 33 feet long by 32 feet 5 inches wide, with an average depth of 3 feet 6 inches.

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* The chlorine figures in Table I. indicate that the effluent of Series I. had apparently picked up some sub-soil water in the long outlet pipe leading to the brook, but this was avoided in the second set of samples by drawing the effluents at the separate outlets from the filters.

(†) *Cf.* Fifth Report, App. IV, Page 1, *et seq.* (‡) *Cf.* Fifth Report, App. IV, Dorking Experiments, page 208, *et seq.*

The primary beds are filled with broken Mendip granite of 1½″ gauge, which rests on a false bottom for drainage. The sewage is distributed in the primary beds by means of walls of slate laid on the Dibdin principle, the walls being 3 feet in width for the full depth of the bed. The beds are so constructed that no liquid is exposed to the air during the filling. The grade and quality of the filling material, the slate distributors and the drainage are intended to facilitate the discharge of humus.

The primary beds discharge their contents automatically on to four secondary contact beds, each 33 feet long by 32 feet 4 inches wide, with an average depth of 4 feet. The primary effluent is distributed over the surface by means of channels which are covered in order to prevent smell. These secondary beds are filled, some with broken Mendip granite of ¾″ gauge, and some with clinker of the same gauge, and, as in the case of the primary beds, the material rests on a false bottom for drainage.

The liquid is discharged from the secondary beds on to four tertiary contact beds, each bed being 33 feet long by 32 feet 4 inches wide, with an average depth of 4 feet.

The tertiary beds have false bottoms for drainage, and are filled with clinker siftings. The secondary effluent is distributed over the surface of these beds by means of open channels.

The tertiary effluent is discharged automatically into a small stream.

The following chance samples were examined :—

Brewery No. 50.

	A. Crude sewage and brewery waste, as flowing into septic tank.	B. Septic tank liquor, drawn from siphon chamber feeding primary bed.	C. Tertiary contact bed effluent. (Two hours' contact in each bed. Primary bed filled the night before).
Sample drawn.	Thursday, October 16th, 1913, 12.10 noon.	October 16th. 12.30 noon.	October 16th.
Sample analysed	October 17th.	October 17th.	October 17th.
Parts per 100,000.			
Ammoniacal nitrogen	4·00	3·51	0·29
Albuminoid nitrogen	0·94	0·97	0·10
Total organic nitrogen	1·99	2·29	0·30
Nitrous nitrogen	—	—	0·02
Nitric nitrogen	—	—	1·53
Total nitrogen (Kjeldahl)	5·99	5·80	2·14
Oxygen absorbed from N/8 permanganate at 27° C. *at once*	2·51	4·66	0·28
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	11·66	16·45	1·24
Dissolved oxygen taken up from tap water at 18° C. *in 3 days*	29·9	52·4	0·43
Dissolved oxygen taken up from water at 18° C. *in 5 days*	32·4	?	0·85
Incubator test (by smell)	—	—	Passed
Chlorine	6·02	4·68	3·76
Solids in suspension	20·4 { 16·4 V. 4·0 N.	19·4 { 16·2 V. 3·2 N.	1·2 { 1·1 V. 0·1 N.
Total hardness (expressed as $CaCO_3$)	—	—	24·8
Permanent hardness (expressed as $CaCO_3$)	—	—	9·7
Acidity due to carbonic acid, sulphuretted hydrogen and organic acids (expressed as H_2SO_4)	5·1	28·3	2·6
Alkalinity (Methyl orange) (expressed as H_2SO_4)	46·2	48·9	29·9
Notes	Brownish turbid liquid, with brown solids; mixed brewery and sulphuretted hydrogen odour. Neutral to litmus in the cold, but alkaline on boiling.	Dark turbid liquor, with fine black solids. Strong brewery septic smell. Much sulphuretted hydrogen. Neutral to litmus in the cold, but alkaline on boiling.	Brownish tinted and slightly opalescent. Very little suspended matter. Faint earthy or wormy odour.

The foregoing analyses show that the samples were not corresponding ones. The tank liquor was somewhat stronger than the mixture of crude sewage and brewery waste, and probably stronger than an average sewage. The tertiary contact effluent was of excellent quality.

Brewery No. 51.

In this case the brewery waste with the sewage from about 120 persons amounts to a total volume of about 50,000 gallons per day.

The mixture first flows through two small septic tanks (total capacity about 3,000 gallons) and then into two large receiving tanks.

From the receiving tanks it is pumped periodically to the double contact beds.

There are four primary beds, each measuring 30 feet by 30 feet, and composed of coarse clinker 3 feet deep. The secondary beds, also four in number, measure 30 feet by 36 feet and are composed of medium clinker 3 feet deep.

Three hours' contact is allowed in each set of beds, which are filled on the average three times a day.

The effluent from the secondary beds is run on to land, where it disappears.

Two chance samples were examined, viz :

Brewery No. 51.

	A.	B.
	Waste liquor, as standing in receiving tank, after passing through the small septic tank. This sample corresponds to the crude waste of the same morning and afternoon.	Secondary bed effluent. Average of eight samples in equal quantities from 4 secondary beds, as discharged between 4.30 and 5 p.m. This sample corresponds to the crude waste of the evening before and early the same morning.
Sample drawn	Wednesday, October 22nd, 1913, 4.0 p.m.	October 22nd, 4.30 to 5.0 p.m.
Sample analysed	October 24th.	October 24th.
Parts per 100,000.		
Ammoniacal nitrogen	2·06	0·98
Albuminoid nitrogen	0·63	0·39
Total organic nitrogen	1·25	0·92
Total nitrogen (Kjeldahl)	3·61	1·90
Oxygen absorbed from N/8 permanganate at 27° C. *at once*	3·67	1·03
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	18·06	4·17
Dissolved oxygen taken up from tap water at 18° C. *in 3 days*	61·9	3·8 approx.
Dissolved oxygen taken up from water at 18° C. *in 5 days*	81·2	8·4 ,,
Chlorine	5·20	5·28
Solids in suspension	5·6 { 4·1 V. 1·5 N.	3·4 { 2·3 V. 1·1 N.
Total hardness (expressed as $CaCO_3$)	—	47·0
Permanent hardness (expressed as $CaCO_3$)	—	4·6
Acidity	Acid from carbonic and other volatile acids.	Acid from carbonic and other volatile acids.
Alkalinity, using Methyl-orange (expressed as H_2SO_4)	43·5	46·2
Notes	Dark and rather turbid liquor, with a strong septic smell. Much sulphuretted hydrogen.	Dark and rather turbid liquor (darker than A). Unpleasant septic and brewery smell. Considerable sulphuretted hydrogen.

Although these two samples were not corresponding ones, the indications are that the effluent was actually derived from a tank liquor of much the same strength as sample A; this latter was very strong, probably equal in strength to a strong sewage.

The effluent, though of poor quality, showed great purification when compared with the tank liquor. It is evident, however, that a brewery tank liquor of the nature and strength of that at Brewery No. 51 should receive not less than three contacts, if it is to be efficiently purified.

Brewery No. 52.

A volume of waste liquid averaging about 270,000 gallons per day (1,500,000 gallons per week of 5½ days) is produced at this brewery.

It gravitates from all parts of the brewery to two underground collecting tanks, and is then pumped to the purification plant. The liquors which contain yeast are first centrifugalised in a patent machine before being mixed with the rest. This removes the great bulk of the yeast.

The mixed waste as pumped from the receiving tanks is first screened and grit-settled under cover, and then treated in primary and secondary contact beds, composed of coarse and medium clinker, respectively. Two hours contact is given in each set of beds.

There are in all twelve primary and twelve secondary beds. The primary beds are composed of coarse, and the secondary of medium, clinker.

The dimensions of the beds are as follows:—

Primary beds:
8 beds - - - - - - 38 feet by 25 feet and 4 feet 3 inches deep.
4 beds - - - - - - 30 ,, 25 ,, 4 ,, 3 ,, ,,

Secondary beds:
8 beds - - - - - - 38 feet by 35½ feet and 2 feet 3 inches deep.
4 beds - - - - - - 35 ,, 20 ,, 2 ,, 3 ,, ,,

The life of the material in the primary beds is stated to be three years. At the end of this time the clinker has to be washed and riddled. The material in the secondary beds has been in use for several years without renewal and still (1913) seems quite clean.

The following chance and average samples were examined:—

BREWERY NO 52.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	Chance sample of screened brewery waste, as flowing from final tank to primary bed.	Chance sample of effluent from primary bed, drawn after valve had been open for 5 to 10 minutes. Bed filled 11 a.m. 2 hours' contact.	Chance sample of effluent from secondary contact bed. 2 hours' contact. (The brewery waste corresponding to this effluent was sent into the primary bed at 9 a.m.)	Average sample of crude screened waste, as filling primary bed, No. 5. This is an average of six sub-samples taken every ten minutes between 8.0 a.m. and 8.50 a.m.	Average sample of primary bed effluent, from bed No. 5. Bed filled 8.0 to 8.50 a.m. Two hours' contact. This sample corresponds to No. 4.	Average sample of secondary bed effluent, from bed No. 7. 2 hours' contact. This is an average of four sub-samples taken every 10 minutes from 12.30 to 1 (mid-day). This sample corresponds to Nos. 4 and 5.
Sample drawn	Tuesday, October 28th, 1913, 12.55 noon.	October 28th.	October 28th.	Wednesday, November, 19th, 1913.	November 19th, 1913.	November 19th, 1913.
Sample analysed	October 30th.	October 30th.	October 30th.	November 21st.	November 21st.	November 21st.
Parts per 100,000.						
Ammoniacal nitrogen	0·76	0·04	0·02	0·72	0·21	0·06
Albuminoid nitrogen	2·40	1·98	0·21	5·68	1·02	0·35
Total organic nitrogen	5·99	2·36	0·39	15·26	2·08	0·68
Nitrous nitrogen	—	—	0·0	—	—	0·0
Nitric nitrogen	—	—	0·0	—	—	0·0
Total nitrogen (Kjeldahl)	6·75	2·40	0·41	15·98	2·29	0·74
Oxygen absorbed from N/8 permanganate at 27° C. *at once*	6·86	3·26	0·58	16·7	3·52	0·82
Oxygen absorbed from N/8 permanganate at 27° C. *in 4 hours*	52·79	36·30	2·27	81·9	50·3	9·80
Dissolved oxygen taken up from tap-water at 18° C. *in 48 hours*	105·2	67·3	1·44	139·6 †	87·0 †	7·86 +x †
Dissolved oxygen taken up from tap-water at 18° C. *in 5 days*	163·5 *	93·3 *	2·90	210·0	121·2	17·6
Incubator test (by smell)	—	—	Failed ; sulphides.	—	—	Failed ; sulphides.
Chlorine	3·30	3·37	3·07	—	—	—
Solids in suspension	50·8 $\left\{ \begin{array}{l} 42{\cdot}0 \text{ V.} \\ 8{\cdot}8 \text{ N.} \end{array} \right.$	11·6 $\left\{ \begin{array}{l} 10{\cdot}6 \text{ V.} \\ 1{\cdot}0 \text{ N.} \end{array} \right.$	4·2 $\left\{ \begin{array}{l} 2{\cdot}4 \text{ V.} \\ 1{\cdot}8 \text{ N.} \end{array} \right.$	206·8 $\left\{ \begin{array}{l} 111{\cdot}6 \text{ V.} \\ 95{\cdot}2 \text{ N.} \end{array} \right.$	11·6 $\left\{ \begin{array}{l} 10{\cdot}5 \text{ V.} \\ 1{\cdot}1 \text{ N.} \end{array} \right.$	4·8 $\left\{ \begin{array}{l} 4{\cdot}2 \text{ V.} \\ 0{\cdot}6 \text{ N.} \end{array} \right.$
Total hardness (expressed as $CaCO_3$)	—	—	24·2	—	—	33·8
Permanent hardness (expressed as $CaCO_3$)	—	—	16·3	—	—	22·1
Acidity due to volatile and organic acids (expressed as H_2SO_4)	46·2	19·3	almost neutral.	44·8	21·8	2·57
Acidity, after boiling	19·3	7·7	—	32·1	12·8	slightly alkaline.
Alkalinity (using methyl-orange) (expressed as H_2SO_4)	18·0	13·5	19·0	13·6	10·7	19·0
Notes	Brownish turbid liquid, with much flocculent suspended matter. Sickly smell of sour beer and sulphides. Strongly acid to litmus, even after boiling.	Brown and turbid. Not very much suspended matter. Sour smell. A good deal of sulphide. Rather strongly acid to litmus, even after boiling.	Brownish and opalescent, with a little suspended matter. Earthy and slightly sour smell.	Brownish and turbid, with much dark coarse and flocculent suspended matter. Sickly brewery smell, with much sulphuretted hydrogen.	Brownish and turbid, with some fine suspended matter. Sour brewery smell. Much sulphuretted hydrogen.	Brownish and rather turbid, with a little suspended matter. Sweetish brewery smell.

* November 3rd, from bottle half-full, which had been kept in ice.

† In 3 days.

Though the chance samples, Nos. 1, 2, and 3, were not corresponding ones, the effluents were in all probability derived from a liquor of much the same quality as No. 1. This liquor was very strong, especially in carbonaceous matter, and took up oxygen rapidly. The effluent from the primary bed, though showing marked purification, was still very impure; that from the secondary bed required only a little further oxidation to make it an effluent of high quality.

The sample of brewery waste, No. 4, was decidedly stronger than No. 1, and consequently the secondary effluent, No. 6, was by no means so well purified as the secondary effluent, No. 3.

Summary as regards Brewery Waste.

We recommend that, wherever practicable, brewery waste should be allowed access to sewers.

Where this is impracticable, such waste can be purified by septic tank treatment and biological filtration through percolating filters, in the manner just described (pp. 109–110). Or it can be purified, either mixed with sewage or not, by tank and contact bed treatment (p. 110 *et seq*). If, from the circumstances of the case, purification by land treatment is easier, only land of quality suitable for sewage-purification, not stiff land, should be used; further, the brewery waste liquor should not be allowed to develop acidity, either before or during its application to the land, otherwise serious nuisance from smell may arise, more particularly if decaying spent hops and yeast are on the ground. As is well known, too, the discharge of unpurified, or imperfectly purified, brewery waste into a stream greatly encourages the development of grey growths in the latter.

In view of all the foregoing results, we think that a reasonable standard for effluents from the treatment of brewery waste and of the liquor from maltings (see below) would be 4 parts suspended solids and 4 parts dissolved oxygen absorption in 5 days.

Steep Water from Maltings.

82. In our Sixth Report we described the way in which steep water was produced in connection with distilleries, and gave the results of some experiments upon its purification by means of biological filtration.

The same kind of liquor is produced from the steeping of barley at maltings, where malt is made for brewing or for extractive purposes.

The procedure differs slightly at every malting, but, as a general rule, the grain is placed in a long, narrow tank, so as nearly to fill it, and then cold water is allowed to flow in at one end of the tank and to overflow at the other end when the tank becomes full. The steeping lasts from 60 to 72 hours, according to the time of year, etc.

The effect of the steeping on the quality of the water is much greater than its brownish tint and slightly opalescent appearance would indicate. The absence of visible signs of deterioration in the water is doubtless the reason why many maltsters look upon steep water as innocuous in character.

As a matter of fact, it is comparable, as regards taking up oxygen from water, with strong domestic sewage, while it also favours excessive development of grey fungoid growth in streams and rivers.

The following analyses, relating to two maltings in Essex, will suffice to show the nature of this steep-water and its variable strength, depending upon the length of time the grain has been in the water :—

	Steep water from malting, No. 53.	Steep water from malting, No. 54.	
	Average of three chance samples taken at the beginning, the middle and the end of the steep.	Chance sample taken after steeping had been in progress for 3 hours, *i.e.*, at the beginning of the steep.	Chance sample taken after steeping had been in progress for 60 hours, *i.e.*, at the end of the steep.
Drawn - - - - - -	January 29th, 1914	January 27th, 1914	January 27th, 1914
Analysed - - - - -	January 30th, 1914	January 29th, 1914	January 28th, 1914
Ammoniacal nitrogen - -	0·09	0·11	0·01
Albuminoid nitrogen - -	0·65	0·43	0·04
Total organic nitrogen - -	1.15	0·50	—
Nitrous nitrogen - - -	—	—	0·0
Nitric nitrogen - - - -	—	—	0·04
Total nitrogen (Kjeldahl) - -	1·24	0·85	Not done
Oxygen absorbed from N/8 permanganate at 80° F. :			
At once - - - - -	3·09	1·95	0·23
In 4 hours - - - -	25·6	33·4	3·14
Incubator test (by smell) - -	Putrid ; black ; H_2S	Putrid ; H_2S	Putrid ; H_2S
Solids in suspension - - -	4·1 (4·1 V.)	—	—
Hardness (as $CaCO_3$) - -	28·4	39·2	29·0
Hardness (after boiling) - -	15·7	16·3	8·6
Alkalinity (with Methyl orange)	40·7	32·9	27·6
Dissolved oxygen taken up from tap water at 65° F. :			
In 48 hours - - - -	—	52·2*	4·5 + x
In 3 days - - - -	27·2	—	—
In 5 days - - - -	38·4	—	—
Remarks - - - - -	Brownish and rather opalescent. A little light-coloured flocculent suspended matter. Slight sweet malt smell.	Brownish and almost clear. Sweetish malt smell. Moderate amount of light suspended matter.	Bright and clear. Slight sweetish malt smell. Trace of suspended matter.

* February 2nd, from a bottle only partly full of sample, which had been kept in ice.

If reference be made to the Sixth Report, p. 31, it will be seen that the above figures are in accordance with those given for the steep water from Mortlach Distillery, from which liquor a uniformly good non-putrescible effluent was obtained by direct filtration through a percolating filter, working at the rate of 25 gallons per cube yard per day.

Summary as regards Steep Water.

Steep water from maltings is a polluting liquor, liable to give rise to objectionable conditions in streams.

It is amenable to biological purification, and a good non-putrescible effluent can be obtained from it at reasonable rates of filtration.

We think that the same requirements, as regards purity of effluent, which we recommend in the case of brewery waste should apply here also.

Waste Liquor from the Manufacture of "Sulphite Cellulose."

83. When wood is digested with a concentrated solution of bisulphite of lime (made by passing sulphurous acid up a tower down which milk of lime trickles), or bisulphite of soda, the matters of the wood other than cellulose are dissolved, leaving the cellulose or wood pulp fibre which is now so extensively used for making cheap qualities of paper. This is an important manufacture in Norway and Sweden, Germany, Canada and the United States, but in Great Britain there are only some four sulphite cellulose mills and, of these, two discharge into the sea.

The sulphite waste liquor itself contains about 10 per cent. of solid matter, of which four-fifths is organic, and constitutes one of the most polluting of all trade wastes. So polluting is it, indeed, that many factories in Germany have been compelled to shut down because of the injury to rivers caused by its discharge, while many of the rivers in America have also suffered severely. The liquor is sterile and has been found to exert a strong germicidal action upon polluted waters.

Although many attempts have been made to convert this waste into useful by-products, none of these, so far as we are aware, has yet been successful on a practical scale. This waste product appears to have been studied more systematically, especially in Germany, than any other of the present day. Nevertheless, there are great possibilities for future investigation. A paper by Mr. Earle B. Phelps*, entitled "The Pollution of Streams by Sulphite Pulp Waste: A Study of Possible Remedies," is worthy of perusal in this connection.

At one of the two mills in this country (No. 55) which we ourselves visited, all the waste liquors are sent to the stream, but the dilution given is great and no serious complaints appear to have arisen. At the other (No. 56) the second and third washings are sent into a small stream. For the greater part of the year the flow of this stream is probably one to three million gallons per day, but in summer its bed may be almost dry. Only these washings, and not the sulphite cellulose waste liquor itself, are discharged into it.

The process, as carried out at Mill No. 56 is as follows:—

Spruce is the wood which is mainly used, one ton of barked wood producing approximately half a ton of cellulose in the form of wood pulp. The wood is broken into rather small pieces and then boiled under pressure in a solution of acid sulphite of lime, in large steel boilers of spherical shape, which are kept revolving slowly.

When the wood is sufficiently softened, the contents of the boilers are run out into a tank with a false bottom of perforated tiles, which retain the pulp, the sulphite liquor being collected below for treatment along with the first washings. This treatment consists in evaporation to dryness, the product being either sold or burnt. Roughly speaking, one ton of barked wood produces 1,200 gallons of this strong sulphite liquor, whose composition was given to us as follows:—

	Per cent.
Organic solids	8·8
Mineral solids	1·2
Organic acidity (mostly acetic acid)	0·4 to 0·6
Sulphurous acid (SO_2)	0·02

After the liquor has drained away, the pulp is washed with clean water, the later washings being sent to the stream. About 1,200 gallons of washings are produced per ton of wood pulped.

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* Massachusetts Institute of Technology. Contributions from the Sanitary Research Laboratory and Sewage Experiment Station (Vol. V.), 1909.

Three samples of these washings, which naturally vary greatly in strength, were collected for examination; they gave the following figures on analysis:—

Parts per 100,000.

	A. Sample drawn at beginning of second wash.	B. Sample from middle of second wash.	C. Weak washings.
Drawn - - - - - - -	January 9th, 1912. 4.30 p.m.	January 9th, 1912. 5.0 p.m.	January 10th, 1912. 12.15 noon.
Analysed - - - - - - -	January 13th.	January 13th.	January 13th.
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.) *at once* - -	122 5	96·8	17·9
Oxygen absorbed from N 8 permanganate at 27° C. (80° F.) *in 4 hours* -	743·3	360·4	76·2
Total solids - - - - - -	962	482	144
Containing matter volatile on ignition	831	352	95
Solids in suspension - - - - -	Not done.	Not done.	3·2
Total hardness (as $CaCO_3$) - - -	113·3	48·6	24·8
Permanent hardness (as $CaCO_3$) - -	Not done.	34·3	17·7
Acidity (as H_2SO_4) - - - - -	77·0	36·8	4·6
Sulphurous acid (SO_2) - - - -	3·2	2·0	0·9

Sample A. was red-brown in colour, with a small amount of fibrous matter in suspension and a strong acid reaction, samples B. and C. possessing the same characteristics in a lesser degree.

As is seen from the above figures, these washings were liquors of high oxygen absorbing power from permanganate. Further, upon a mixture of 2 per cent. of Ealing sewage and 98 per cent. of tap water, quantities of A. up to 2 per cent. and probably up to 10 per cent. (or even more) had apparently no power to prevent the absorption of the dissolved oxygen of the water by the sewage. It is to be inferred from this that sulphite cellulose washings, unless in too large relative proportion, might reasonably be run into sewers. A fortnight later (after the sulphurous acid in A. had been reduced from 3·2 to 1·6 parts per 100,000, and when germicidal power had therefore become weakened), Sample A., whether diluted or undiluted, did not kill *B. coli* after one hour's contact.

Summary as regards Sulphite Cellulose.

The washings from the manufacture of sulphite cellulose are highly polluting, and of course the crude liquor itself is much more so. As has already been said, there are only one or two sulphite cellulose works in this country, so that the question of treatment is not very urgent at the moment. We are disposed to think, however, that the crude liquor and first washings should not in any circumstances be allowed to discharge into a stream. Possibly improved procedure in washing with smaller quantities of water may reduce the aggregate amount of impurity to be discharged. In course of time some practicable means may be found for purifying the weaker washings by themselves.

The Metal Industries.

84. At the majority of the works connected with the production of the commercial metals, such as iron, nickel, etc., or the manufacture of steel or brass, comparatively little water is used. As a rule, the purity of this water does not become seriously impaired. The pollution arising from the metal industry, as a whole, is thus relatively small.

At a number of works, however, as for instance, tin-plate works, galvanizing works, wire works and brass foundries, acids are used at some stage in the manufacturing process, mainly for the purpose of removing rust from the surface of the metal or alloy which is being dealt with.

The acids commonly used are sulphuric and hydrochloric. Nitric acid is used to some extent in brass works.

The result is a strong solution of the sulphate, chloride or nitrate of the metal or metals, as the case may be. This solution always contains a large proportion of free acid.

In some cases where sulphuric acid is used in connection with iron, the contents of the "spent" acid bath are evaporated for the recovery of the ferrous sulphate, but, as a rule, the solution is discharged as a waste liquid.

Many works are situated in towns, and in such cases, where the volume of liquor is not great in comparison with the volume of the sewage, it is usually discharged into the public sewers.

Other works, however, are situated in rural districts and produce a considerable volume of waste liquor. Of these, tin-plate works may be cited as an example.

The manufacture of tin-plates may be described briefly as follows:

Steel bars are rolled into thin plates of various sizes and thicknesses, which, after cooling, are dipped into a strong solution of sulphuric acid, or sometimes hydrochloric acid, to remove scale and rust. The plates are annealed, to make them soft, and are subsequently dipped again in a weak solution of acid. After being lifted out of this acid and allowed to drain for a minute or so, the small quantity of acid adhering to them is washed off in a bath of water, and the now clean plates are dipped in molten tin or zinc, as the case may be.

There are two waste liquors from the process, viz.: (1) The mixed acid liquors from the first and second dippings; and (2) the water in which the plates are rinsed, this latter being termed the "swilling fluid."

(1) *The acid bath* eventually becomes a strong solution of sulphate (or chloride) of iron, and it has always an acid reaction. The sulphate of iron is usually, but not always, recovered from it by evaporation in lead-lined tanks heated by steam, and subsequent crystallization, the product (copperas) being sold. We understand that the price of this fluctuates a great deal—from about 6s. or 7s. to 20s. per ton. If 12s. 6d. per ton can be obtained, the recovery process is a profitable one.

At the end of each week the insoluble deposit which has accumulated in the crystallizing tanks is flushed out with water into settling ponds. The mother liquor, previously run off from this deposit, is used for the next crystallization.

When hydrochloric acid is used for the dipping, the contents of a bath are generally discharged direct to a stream or into the sewer.

(2) *The "swilling fluid."*—Since it is important to remove all the acid from the plates, a continuous flow of water is usually passed through the washing bath. A large volume of swilling fluid (60,000 to 70,000 gallons per week at one works visited) is thus produced, and as the quantity of sulphate of iron in it is very small, evaporation is probably out of the question. The liquor is decidedly acid. As a rule, it is sent direct to the stream, where it produces the same effect as the ferruginous water from a coal mine. Its admixture with the carbonates of lime and magnesia of the river water and its oxidation by the dissolved oxygen of the water cause the iron to be gradually deposited as a light yellow-brown and very finely-divided precipitate (probably a basic carbonate of iron), the water and bed of the stream being coloured for a great distance, unless the dilution is very large. The discharge is said to be very injurious to fish.

The main centres of the industry are Glamorgan, Staffordshire, and Glasgow. In Glamorgan, the tin-plate works are usually situated near the mouths of the numerous short rivers of that county. In most of these rivers there are, practically speaking, no fish, owing to the discharge of this liquor and of the coal-washing water into the upper reaches.

In Glasgow the iron liquors are taken into the sewers.

In Staffordshire, the works are at the top of a watershed, and considerable damage to streams is said to arise.

The following analyses of crude swilling fluid (Sample 152) and of general effluent (Sample 153) from Tin-plate Works No. 57, in South Wales, have been made.

No. 152 was an average sample of swilling fluid, taken in two equal portions every half hour, over the greater part of a working day in December, 1909 (one portion just after the plates had been dipped, and the other just before they were drawn out).

The liquor is not discharged separately at this works, but is mixed with a large volume of condensing water, the mixture being given considerable settlement (probably about eight hours) in three roughly constructed earth ponds, used in series. The settled liquor then flows through a long ditch which discharges into a small river below a weir.

The heavier suspended matter in the swilling fluid settles in the ponds, where some precipitation also takes place, but the liquor as discharged into the river contains a good deal of red flocculent iron precipitate.

No. 153 was an average sample of the effluent as discharged. It consists of the liquid of No. 152, diluted with condenser water. Its temperature was 27° C. (80° F.)

TIN PLATE WORKS NO. 57.

	No. 152.	No. 153.
	Crude swilling fluid. Taken every half-hour from 9 a.m. to 4 p.m., excepting during the dinner hour.	General effluent. Taken in the same way as No. 152, just where the effluent joins the river.
Temperature of Sample.	15° C. (59° F.)	27° C. (80° F.)
Date when sample was drawn.	December 15th, 1909.	December 15th, 1909.
Date when sample was analysed.	January 24th, 1910.	January 24th, 1910.
	Parts per 100,000.	
Ammoniacal nitrogen - - - - -	0·0	0·0
Albuminoid nitrogen - - - - -	0·16	0·08
Total solids - - - - - - -	469·4	179·8
Solids in suspension - - - - - -	8·1 { 3·8 V. 4·3 N.	3·8 { 1·8 V. 2·0 N.
Ferrous iron (Fe^{ii}) - - - - - -	114·8	41·8
Ferric iron (Fe^{iii}) - - - - - -	10·0	9·9
Equivalent to Ferrous sulphate ($FeSO_4$) - - - -	312·0	113·5
Ferric sulphate ($Fe_2(SO_4)_3$) - - - -	35·7	35·4
Total acidity, as H_2SO_4, measured by titration with potash solution - - - - -	325·9	113·3
Total acid combined with iron (as H_2SO_4) -	227·5 } =325·6	99·2 } =113·2
Additional acid (as H_2SO_4) - - - -	98·1	14·0
Notes - - - - - -	When drawn, this was grey-brown in colour with a slight metallic odour, and with no tendency to froth on shaking. The suspended matter was flaky. Apart from the suspended matter, the liquid remained clear for a long time, even when there was much air in the bottle.	This was slightly opalescent when drawn, with practically no odour. The small quantity of suspended matter was reddish-brown. With air subsequently in the bottle, the liquid gradually deposited a red iron precipitate.

It will be seen that the swilling fluid itself is, practically speaking, a dilute solution of ferrous sulphate containing a considerable quantity of free sulphuric acid as well as some suspended matter.

There can be little doubt that considerable injury to streams would arise from the discharge of such a liquid, unless the dilution were very great. The water, in addition to being discoloured, would be rendered acid and very hard, and the bed of the stream would be fouled with a ferruginous deposit.

The analysis of the effluent from the settling ponds shows, as might be expected, that settlement alone does not materially improve the "swilling fluid" from tin-plate works.

In this particular case, the admixture of condensing water and the exposure to air in the settling ponds had the effect of converting some of the iron into the ferric state, but the effluent, though more dilute, was of the same general character.

The following statement relating to tin-plate works in Glamorgan was handed in by the late Dr. W. Williams, Medical Officer of Health to the Glamorgan County Council, in giving evidence before us on October 12th, 1902 (Third Report (Evidence) pp. 187–188) :—

"There are some forty tin-plate works in the county of Glamorgan and a few at present idle. Of these, eight are situated on the sea-shore, ten on tidal rivers, and twenty-two on non-tidal rivers.

"At two of these works 'black plate' alone is produced, and therefore no acids are used. At the remaining works, crude vitriol is used, and the pickle is converted into copperas. In several cases the copperas tanks, etc., are out of repair, allowing considerable soakage and consequent pollution of adjoining stream and rivers; frequent examinations of these premises are therefore essential.

"The three works at which copperas is not made are situated quite inland and on the same river, namely, the Taff, once well known as a fishing river.

"At one of these works the pickle is pumped on to large cinder heaps, which are always present in the vicinity of these works. The acid is spent by coming into contact with the iron in the cinders. The sulphate of iron produced may, however, be dissolved by surface water and carried in solution to the adjoining river, and although the effluent thus produced is not seldom found discharging through any particular channel, yet the chemical analyses of samples taken from adjoining streams and rivers are often found to contain free acid and sulphate of iron, as is shown to be actually the case, thus :—

ANALYSIS OF TIN-PLATE EFFLUENTS.

Results stated in parts per 100,000.

No.	Date Collected.	Acidity (Free Sulphuric Acid).	Iron (Fe).
1	April 23rd, 1902	0·98	28·5
2	June 13th, 1902	2·4	28·9

"I am of opinion that the conversion of the 'pickle' into copperas, wherever the works are situated, should be insisted upon, and that facilities should be given at all reasonable times for the taking of samples and inspection of the works by persons employed by County Council and local authorities. With regard to the latter my experience is that they but seldom take any samples or inspect these works; on the other hand, some local authorities in Glamorgan are in the habit of occasionally inspecting these works and reporting thereon to me.

Swilling Fluid.—The swilling fluid is very much weaker than the pickle, but in volume very much larger, and to get rid of the free acid and sulphate of iron it contains is a difficult problem.

"The analysis of two samples of swilling fluid taken as it leaves the tanks is given below.

No.	Date Collected.	Acidity (Free Sulphuric Acid).	Sulphate of Iron ($FeSO_4$).
1	March 19th, 1902	168·5	334·4
2	March 26th, 1902	41·1	574·5

"It is only in one instance that any attempt is being made to purify the swilling fluid. In this case the effluent is made to pass through several sets of limestone bays, the action being partly mechanical and partly chemical, producing oxide of iron and sulphate of calcium which are deposited. No doubt some purification results from this method, but in practice it is found that the limestone becomes coated with a yellow deposit and the action of the acid upon it ceases.

"The broken limestone should be frequently changed and washed, and if this is not done the deposit on this prevents further action. The water in this river below the works is used for drinking purposes by animals.

"Whether the 'swilling fluid' should be treated or not depends upon circumstances existing in connection with the works such as :—

(*a*) The situation of the works; and

(*b*) The uses made of the river's water below the works.

"1. If the works are on the sea, and not near the estuary of an important river, as some are, then there would be no need of purifying the effluent.

"2. When the works are situated on estuaries containing large volumes of water, there would, under these circumstances, be no need of purifying the effluent.

"3. When the works are situated on tidal rivers, it may or it may not be considered necessary to purify the effluent. This would depend on the quantity of water contained at various seasons in the river at the point where the effluent is discharged, and whether the river's water would, by the admission of the effluent, be rendered inimical to fish life.

"In Glamorgan, all works on tidal rivers discharge the swilling effluents untreated into the adjoining rivers.

"4. When the works are situated inland on non-tidal rivers, as the greater number of our works are in Glamorgan, matters are different, and here the great difficulty arises.

"Here again local circumstances must be taken into consideration, such as the volume of water in the river in the dry seasons, and whether the river's water is used for drinking purposes by man or animals, or otherwise made use of below the works.

"At one tin-plate works in Glamorgan the 'swilling effluent' is treated as above described, and preparations are being made at two other works to treat the effluent in a similar manner."

Reference should also be made to the evidence given by Dr. Williams and by Colonel Lewis, Chairman of the Sanitary Committee of the Glamorgan County Council, on January 27th, 1909.

The Rivers Pollution Commission of 1868, in dealing with the pollution arising from metal manufactures (Fifth Report, Section B., Remedies, p. 46), reported as follows :—

"The remedies for river pollution arising from metal manufactures are most of them of a very obvious and simple character. We have already stated in the description section of this report that the only really serious pollution caused by the metal trades is that occasioned by tin-plate and galvanizing works. The metalliferous liquors discharged from such works together with those sometimes allowed to escape in much smaller quantities from brass foundries, German silver works, and electro-plate factories, contain metallic salts, which, in all well regulated works, are manufactured into marketable products and sold; or they are sometimes disposed of in their crude condition to chemical manufacturers, who utilise them for various purposes. At Messrs. Thompson, Morgan & Co.'s Tin-plate Works at Broadwaters, near Kidderminster, the waste pickling liquor is concentrated in shallow leaden evaporating pans, until, on cooling, it deposits a copious crop of crystals of green copperas which is sold at a small profit; the mother liquor from these crystals is fortified with fresh sulphuric acid and used over again, none being allowed to go into the river. In this way all the sulphuric acid used in tin-plate and galvanizing works would become transformed into marketable green copperas, yelding a profit to the manufacturer instead of poisoning the fish in the rivers or destroying the brickwork of the sewers, into which it is now in many cases discharged, in utter disregard of injury to the property of others. The remedy for river pollution from the muriate of iron produced in such works is equally simple, but does not hold out so certain a hope of profit. The crude waste liquor may be concentrated by evaporation and sold as a disinfectant, for which purpose it is valuable; or it may be decomposed by lime or a mixture of chalk and lime, which would transform the polluting muriate of iron into non-polluting muriate of lime; the oxide of iron precipitated by the lime may be sold to iron smelters or gas manufacturers, or dried in the ash-pits of the numerous furnaces employed in such works and then carted away with the ashes. The prohibition of the discharge of metalliferous liquids from tin-plate and galvanizing works into rivers and town sewers, would inflict no serious hardship upon manufacturers, whilst it would preserve much valuable property which is now injured or destroyed by these noxious chemicals. Still less hardship would result from the similar prohibition of such discharges from nickel, iron and steel wire, German silver, and electro-plate works, and from brass foundries, because the liquids are of comparatively much smaller volume, whilst the metallic salts, which may be extracted from many of them, are of far higher value than those obtainable from tin-plate and galvanizing works. Where the nickel, German silver, electro-plate and brass factories are situated in towns, such waste liquids as their owners choose to discharge may be, owing to their comparatively small quantity, safely admitted into town sewers. They will not, for the same reason, interfere with the subsequent utilisation or purification of the sewage.

"The pollution arising from the carrying on of the cutlery trade is essentially solid rubbish. The waste 'wheel swarth,' being the grit produced during the grinding process, has indeed a certain value which should make the discharge of it as mere rubbish very easily preventable. It is used in the formation of a cement for the construction of the converting furnaces in which steel is manufactured; and some manufacturers not only employ all their own waste sand for this purpose, but have to purchase that of others. The remedy for its wilful casting into rivers is, therefore, simply prohibition under adequate penalties.

"There now remains only the drainage from iron works and rolling mills, the polluting matter of which is entirely in suspension and but small in quantity; and we have only to add that, where necessary, filtration, or subsidence for six hours, would effectually cleanse all such liquids at a very reasonable cost to the manufacturer."

Summary as regards the Waste Liquors from Metal Industries.

The liquor from galvanizing, wire-drawing, and tin-plate works is an acid solution of either sulphate or chloride of iron. It has a most serious effect on the water of a stream, and we are of opinion that in those cases where it cannot with advantage be discharged into sewers, it ought to be evaporated. This is not a difficult matter with the sulphate liquor, but it may be rather costly in the case of the chloride. Hydrochloric acid pickle has been treated on a large scale with milk of lime for the recovery of the iron as oxide.

With regard to the washings, it would probably be quite practicable to neutralise the acid and precipitate the iron by the use of lime or of carbonate of lime, but we know of no experiments on this point on an out-of-door scale; the resulting liquor would be very hard. Satisfactory quantitative experiments have, however, been made in the laboratory, with lime and with carbonate of soda as the precipitants. In the latter case the resulting effluent is not hard.

Fellmongers' Waste.

85. The business of the fellmonger is to remove the wool from sheep skins so that it may be sent to the woollen merchant and the pelts or skins to the tanner.

The processes carried out by the fellmonger are as follows :—

(1) The skins are " soaked " in cold water for the purpose of removing dirt and blood adhering to them.

(2) They are then either painted on the inner side with a depilatory, such as a mixture of lime and realgar (sulphide of arsenic), or of lime and sodium sulphide, or they are soaked in milk of lime.

(3) The wool loosened by one or other of these processes is removed by means of a blunt two-handled knife and is roughly sorted at the same time.

(4) The wool is dried.

(5) The pelt or skin is soaked in strong milk of lime, or pickled in dilute sulphuric acid, to prevent it putrefying on the way to the tanner.

Three or four days suffice to complete the whole process, as a rule.

The trade, comprising some 250 " yards," is widely scattered over Great Britain and Ireland, being almost always carried on in towns and on a small scale. There are, however, some large " yards," notably in London, at Milnrow in Lancashire, and also in Yorkshire. In most cases the business premises of the fellmonger are situated in a thickly-built area.

In a great many cases fellmongering is carried on in conjunction with tanning, and although most of these tanneries are situated in towns, there are also a considerable number in rural districts.

As a general rule, the fellmonger deals with skins from freshly-killed sheep, while the tanner may deal either with dried and salted bullock hides or goat skins of foreign and colonial origin, or with the skins of animals freshly killed in this country. Sometimes the tanner deals with both classes together.

The waste liquors from fellmongering are derived from the soaking of the skins in water and in milk of lime.

The former process is usually carried out in a brick tank or " pit " sunk into the ground, so that the skins may be easily handled. A single charge of water in this pit is used for soaking a large number of skins. When it becomes too foul for the purpose of cleansing, it is discharged.

The skins are by no means thoroughly cleansed in this " soaking " process, but the liquor is nevertheless exceedingly foul. It is usually tinted reddish-brown with blood and it always contains much suspended organic matter.

At some works a continuous flow of water is passed through the " soak " tanks, and at the larger " yards " the skins, after removal from the soak pits, are sometimes further washed by means of a " burring " machine, which works in conjunction with a spray of water. In such cases the waste liquor is not so strong, but there is, of course, much more of it.

The liming is also done in brick pits sunk in the ground, the skins being left in contact with the milk of lime for a period of time which ranges from 4 or 5 hours to 2 days, after which they are drawn out, packed in bales and sent to the tanner.

The milk of lime is run off from the pits when it becomes too foul for further use, usually after two or three days.

It is a greenish-white turbid liquid, possessing a putrid and ammoniacal smell. It contains much insoluble lime and carbonate of lime in suspension, together with small pieces of flesh and some hair.

Where sulphide of arsenic or of sodium is used as a depilatory, this is also to be found in the liquor.

The total volume of waste liquor produced by a fellmonger is not large. It varies from about 500 gallons per working day at a small yard to something like 10,000 gallons per day at a large one.

The following analyses, relating to samples of " soak " and " lime pit " waters, will give an idea of the general composition of such liquors. The samples were taken at Fellmonger's yard No. 58, in Bermondsey, where the skins of freshly-killed sheep are dealt with.

FELLMONGERS' YARD No. 58.

Parts per 100,000.	No. 1. Chance sample of "Soak" water from the Soak tank.	No. 2. Chance sample of liquor from the lime pit in which all pelts are placed after hair has been removed.	No. 3. Chance sample of liquor from the lime pit in which pelts are finally placed before being packed.	No. 4. Chance sample of "Soak" water from the Soak tank.	No. 5. Chance sample of liquor from the lime pit in which pelts are finally placed before being packed.
Sample drawn	Mar. 11th, 1912, 12 noon.	Mar. 11th, 1912, 12.15 noon.	Mar. 11th, 1912, 12.20 noon.	Mar. 29th, 1912.	Mar. 29th, 1912.
Sample analysed	Mar. 13th, 1912.	Mar. 12th, 1912.	Mar. 12th, 1912.	April 1st, 1912.	April 1st, 1912.
Ammoniacal nitrogen	1·57	11·25	14·10	4·30	5·80
Albuminoid nitrogen	0·88	40·0 + x.	48·0	3·55	21·1
Total organic nitrogen	2·03	94·6	118·2	12·55	51·0
Nitrous and nitric nitrogen	0·11	—	—	—	—
Total nitrogen (by Kjeldahl)	3·71	105·9	132·3	16·9	56·8
Oxygen absorbed from N/8 permanganate at 27° C.— At once	2·35	70·4	79·6	14·2	40·4
In 4 hours	12·58	208·1	221·2	55·8	119·2
Chlorine	18·7	—	—	—	—
Hardness (by Soap Test, expressed as $CaCO_3$)	59·7	0·0*	0·0*	—	—
Hardness after boiling (by Soap Test, expressed as $CaCO_3$)	25·7	—	—	—	—
Total solids	164·5 { 54·5 V. 110·0 N.	1931·0 { 481·5 V. 1449·5 N.	1596·5 { 725·5 V. 871·0 N.	490·5 { 183·5 V. 307·0 N.	651·0 { 400·0 251·0 N.
Solids in suspension	16·5 { 8·9 V. 7·6 N.	— —	— —	121·0 { 44·5 V. 76·5 N.	52·0 { 18·5 V. 33·5 N.
Fatty matter (extracted with ether, after acidifying, etc.)	—	27·7 (27·7 V.)	9·7 (9·7 V.)	67·6 (66·4 V.)	2·3 (2·3 V.)
Dissolved oxygen taken up from water at 18·3° C.— In 48 hours	6·35	560·0	600·0	—	—
In 5 days	18·10	1025·0	860·0	—	—
Alkalinity (expressed as H_2SO_4):		*Paper-filtered.*	*Paper-filtered.*	*Paper-filtered.*	*Paper-filtered.*
Free alkalinity, due to caustic lime	—	1217·0—248·0	533·9—248·3	14·4 —10·2	137·0— 92·0
Alkalinity due to carbonate	39·7	198·6—111·6	186·3—149·0	— —	92·0— 91·0
Total alkalinity	39·7	1415·6 359·6	720·2 397·3	— —	229·0 183·0
Remarks	Brown and turbid liquor with some fine brown suspended matter. Slight stale smell.	Very turbid with white suspended matter. Foul, sickly smell.	Very turbid with white suspended matter. Foul, sickly smell.	Reddish-brown liquor with much suspended matter. Foul smell.	Very turbid with white suspended matter. Foul and sickly smell.

* Done on paper-filtered sample.

These figures show that both kinds of waste are very polluting, the lime liquor being excessively so. The weaker of the two "soak" waters is about as strong as a domestic sewage of rather under average strength, while the weakest of the lime liquors is certainly 10 or 15 times as strong as an average domestic sewage. All the lime liquors are also strong solutions of lime.

The following analytical figures, relating to samples drawn at Yard No. 59, in the West Riding of Yorkshire, may be given with the object of showing that settlement of fellmongers' waste still leaves a very polluting liquor for discharge. At this yard the soak water and the lime liquor are merely allowed to flow through small settling tanks before entering the stream.

FELLMONGER'S YARD NO. 59.

Parts per 100,000.	No. 1. Soak water as flowing into settling tanks from two pipes. Chance sample.	No. 2. Lime pit water as flowing into settling tank. (The volume of this is about one-tenth of the volume of soak water).	No. 3. Effluent from settling tanks as flowing to stream.	No. 4. † Effluent from settling tanks as flowing to stream.
Drawn - - -	March 23rd, 1914. 3.8 p.m.	March 23rd, 1914. 3.10 p.m.	March 23rd, 1914. 3.30 p.m.	Dec. 11th, 1913.
Analysed- - -	March 25th, 1914.	March 25th, 1914.	March 25th, 1914.	Dec. 15th, 1913.
Ammoniacal nitrogen -	1·50	21·9	1·12	0·19
Albuminoid nitrogen -	4·15	40·6	3·66	0·68
Total organic nitrogen -	10·68	68·7	7·73	1·58
Nitrous nitrogen - -	—	—	—	0·00
Nitric nitrogen - -	—	—	—	1·52
Total nitrogen (Kjeldahl)	12·18	90·6	8·85	3·29
Oxygen absorbed from N/8 permanganate at 27° C. *at once* - -	16·8	60·4	8·35	1·64
Oxygen absorbed from N/8 permanganate at 27° C. *in* 4 *hours* -	55·0	214·0	29·8	6·96
Chlorine - - - -	20·0	92·3	40·3	—
Hardness (as $CaCO_3$) -	—	—	—	34·4
Hardness (after boiling; ,,)	—	—	—	29·7
Solids in suspension -	169·6 { 47·2 V. 122·4 N.	(?) 89·2 * { 43·2 V. 46·0 N.	23·1 { 10·3 V. 12·8 N.	10·0 { 5·5 V. 4.5 N.
Alkalinity (as H_2SO_4):				
Caustic alkalinity (phenol-phthaleïn) -	90·4	132·3	32·7	7·7
Total alkalinity (Methyl orange) - - -	126·4	231·3	55·8	20·6
Alkalinity (after boiling): Phenol-phthaleïn -	—	—	—	10·9
Dissolved oxygen taken up from tap water at 18° C.:				
In 48 hours - -	45·0	181	26·7	5·9 *Paper-filtered.*
In 5 days - -	80·0	446	57·1	15·0—11·7
Remarks - - - -		* Only very approximate.		Brownish and opalescent. Considerable quantity of fine light coloured suspended matter. Unpleasant tannery smell.

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† No lime liquor was flowing into the settling tanks at the time this sample was drawn. It therefore represents settled soak water.

These figures hardly require comment. The effluent from the dilute "soak" water took up 15 parts of dissolved oxygen in 5 days, while the effluent from the mixed "soak" water and "lime" liquor took up 57·1 parts. As regards polluting power, this latter effluent may be compared with a strong domestic sewage.

A few experiments were made on the biological filtration of fellmongering wastes through a small matured laboratory filter of fine clinker, similar to that used in the corresponding experiments on tannery waste. These may be shortly summarised as follows :—

Experiment No. 1.—*March* 21*st to* 26*th*, 1912.

The liquor consisted of a mixture of the samples drawn on March 11th, in the following proportions :—

		c.c.	
Sample	1. Steep water	550	
,,	2. Primary lime pit water	40	
,,	3. Secondary lime pit water	210	=800
,,	4. Tap water		2,000

When these lime waters were mixed with the rather hard tap water, the effect was of course, to neutralise the caustic alkalinity and to throw down a large precipitate of carbonate of lime.

The figures in the following table shew the results of the filtration :—

Parts per 100,000.	Original liquor.	After first filtration at a rate of 170 gallons per cube yard per 24 hours (for 12½ hours).	After second filtration at a rate of at least 50 gallons per cube yard per 24 hours (for 46 hours).	After third filtration at a rate of 43 gallons per cube yard per 24 hours (for 20 hours).	After fourth filtration at a rate of 32 gallons per cube yard per 24 hours (for 18 hours).
Ammoniacal nitrogen -	1·97	0·74	1·72	1·36	0·93
Albuminoid nitrogen -	3·96	1·52	0·59	0·32	0·24
Nitric nitrogen - -	—	0·5 approx.	1·6	3·2	4·7
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours - - -	23·9	7·71	3·52	2·08	1·76
Incubator test (by smell) -	—	Failed (H_2S).	Passed (Musty smell).	Passed (Clean smell).	Passed (Clean smell).

The *average* 24 hours' rate per cube yard at end of 2nd filtration was - 37 gallons.
,, ,, ,, 3rd ,, ,, - 20·5 ,,
,, ,, ,, 4th ,, ,, - 12·5 ,,

Experiment No. 2.

Made with sample drawn on March 29th, 1912.

The mixture filtered consisted of the steep liquor diluted with 3 volumes of tap water :—

Parts per 100,000.	Original liquor.	(*a*) After one filtration at a rate of 10 gallons per cube yard per 24 hours (for 116 hours).	(*b*) After one filtration at a rate of 30 gallons per cube yard per 24 hours (for 24 hours).
Ammoniacal nitrogen - - - -	1·82	0·04	—
Albuminoid nitrogen - - - -	0·68	0·08	—
Nitric nitrogen - - - --	—	2·32	1·5 to 2·0 approx.
Oxygen absorbed from N/8 permanganate at 27° C.—in 4 hours - -	11·3	0·81	2·10
Incubator test - - - - -	—	Passed.	Not done.

Experiment No. 3.

Made with sample drawn on March 29th, 1912.

The mixture filtered consisted of liquor from lime pit diluted with 9 volumes of tap water :—

	Original liquor.		After filtration at a rate of 38 gallons per cube yard per 24 hours (for 43 hours).
Ammoniacal nitrogen	0·52		0·03
Albuminoid nitrogen	2·00		0·14
Nitric nitrogen	—		1·60
Oxygen absorbed from N/8 permanganate at 27° C. —in 4 hours	10·42	Paper-filtered. 9·81	0·74
Incubator test	—		Passed (clean smell).

The lime pit water was very foul and turbid, with much caustic lime in solution. The copious precipitate of carbonate of lime brought down on diluting with tap water left the liquid clear, but hardly lessened the amount of organic impurity present, as judged by the "oxygen absorbed" in 4 hours.

The foregoing figures of Experiments 1 to 3 require practically no explanation. They show that fellmongering waste liquors, taken either separately or mixed, are readily amenable to biological filtration after the free lime present in the lime pit liquor has been carbonated.

Summary as regards Fellmongers' Waste.

It is clearly evident from the experiments just quoted that the organic matter of this highly objectionable waste is not likely to cause any difficulty in the purification of sewage which contains it in moderate quantities.

Indeed, in many cases, the lime which the fellmongers' waste contains would be beneficial from the point of view of sewage purification. It would help to keep the sewage alkaline and so tend to prevent nuisance from smell. On the other hand, if the discharge of lime water or milk of lime were large in relation to the total flow of sewage and the size of the sewer, there would be danger of accretions forming in the sewer.

In view of the fact that fellmongers' yards are usually in towns, and that only small volumes of waste liquor are produced, we are led to recommend that the waste should, wherever possible, be allowed access to public sewers.

In order to avoid the possible silting up of sewers in dry weather, the mixed lime liquor and "soak" water should be passed through a large catch pit before being so discharged. In the generality of cases we think that no treatment other than this by the manufacturer would be necessary.

In those isolated cases where access to sewers is impracticable, the waste ought to be purified by the fellmonger himself. It is of so foul a nature that nothing short of thorough purification, or very large dilution, would suffice to prevent nuisance or injury occurring in a river which received it.

Our experiments have not gone far enough to indicate the conditions under which the best results could be obtained or the amount of filtering material which would be required for the adequate purification of fellmongers' waste. Large scale experiments upon these points should be carried out.

We see no reason to doubt, however, that it will be found practicable to purify fellmongers' waste to the same extent as we have suggested for tannery waste, that is, to produce an effluent from it which contains not more than 4 parts of suspended matter and takes up not more than 4 parts of dissolved oxygen per 100,000 from water.

Tannery Waste.

86. Tanning is the name given to the chemical process by which the putrescible skins of animals are converted into non-putrescible insoluble leather. There are many different ways of carrying out the process, but five methods are in common use in the British Isles at the present time. In one of these the skin is tanned by long contact with oak bark in water; in another by means of strong infusions of concentrated bark or other vegetable extract; chrome leathers are made by tanning with bichromate of potash; glove leathers with alum; and chamois leathers with cod liver oil.

As a rule different "tannages" are employed, according to the class of skin dealt with, oak bark tanning being used for bullock skins, chrome tanning for goat and calf skins, and vegetable extract, alum and oil tanning for sheep skins.

It is probably correct to say that no two tanners use precisely the same tanning process. Nevertheless, the procedure in a tannery usually follows certain well defined lines. First, the skins are soaked in water to remove dirt and blood, or, if they are cured and salted skins, to remove soluble preservatives and to moisten the skin thoroughly. Considerable time is sometimes required to bring about thorough moistening of cured skins, and the process is sometimes hastened by the use of formic acid.

Except in the case of those yards where furs and skin rugs are tanned, the next process is that of "unhairing," in which the hair is first loosened at the roots and then scraped off with a blunt knife. The loosening of the hair is sometimes effected by allowing the wet skin to putrefy in a warm room, but the more usual plan is to paint the underside of the skin with a depilatory mixture—such as lime and sulphide of sodium, or lime and realgar (sulphide of arsenic)—made up in the form of a paste. In other cases, where the hair is not very valuable, the skins are simply soaked in milk of lime.

After the hair or wool has been removed, the "unhaired" skin or "pelt" is thrown into a pit or a succession of pits containing strong milk of lime, to "plump" the pelt and to prevent it putrefying. The time required for this liming process varies according to the hide and the season of the year. The range is from two or three days to three weeks.

After being taken from the lime pits the hides or pelts are "de-limed," *i.e.*, they are subjected to some process which removes, more or less completely, the free lime and lime salt which has permeated the skin. Heavy leathers are merely washed in soft water or dipped in dilute acid, but fine leathers are either soaked in a mixture of water and hen excrement ("bateing") or dog excrement ("puering"), and after one or other of these processes they may undergo a second de-liming process called "drenching," in which they are placed in an infusion of bran and water which undergoes fermentation and generates organic acid.

The de-limed hide or pelt is then tanned by immersion in a solution of oak bark, or of bichromate of potash, alum, etc.

The tanned leathers are finally finished, *i.e.*, fat-liquored, stuffed, curried, dyed, polished or japanned, according to their class and intended use.

Waste liquors are derived from the following processes:

(1) Soaking.
(2) Liming.
(3) De-liming.
(4) Tanning.
(5) Dyeing.

Small quantities of waste liquor, consisting of dirty oily water, are also derived from "fat liquoring," but water is not used to any extent in the other finishing processes.

All of these waste liquors are polluting in character, but the lime water and the soak water are so excessively foul and of so large a volume in comparison with the other liquors that they impart their characteristics to the whole waste, and, from a purification point of view, bring all tannery wastes more or less into line. The waste liquors from "bateing" and "puering" are also highly polluting, but being valuable they are conserved as much as possible, and they do not usually represent more than a small proportion of the total volume of waste liquor from a tannery where these processes are carried out.

The waste tan liquors may be residual infusions (frequently very strong ones) of oak bark, oakwood extract, sumach, valonia, myrobalans, etc., an acid solution of chromium salts with some excess of thiosulphate,* or, in the case of oil tanning, a greasy solution of sodium sulphate. All waste tan liquor contains much suspended matter in the form of pieces of skin and flesh, and, in the case of vegetable tannages, of insoluble matter from the bark, etc.

As waste tan liquors from oak bark and vegetable and chrome tannages always contain much unspent tanning substance, they all yield a heavy precipitate when mixed with the waste liquor from the lime pits. This is a point of much significance in connection with the preliminary clarification of tannery waste, or with its discharge into sewers.

The total volume of waste liquor from a tannery varies very considerably, according to the kind and amount of work carried out. A small tanyard may produce about 2,000 gallons of liquid waste per working day, and a large one as much as 100,000 gallons or more. As a rule, the volume is small compared with that from works connected with the cotton, woollen or paper trade, but its character is exceptionally polluting.

We have not succeeded in finding any exact records of the number of tanneries in the British Isles, but from the data before us we should estimate that it is not far short of 400, including both large and small yards. About one-third of the number are situated in six centres, namely, London, Warrington, the Leeds district, Manchester, Liverpool and Glasgow, and the remainder are scattered widely over the country. In the great majority of cases they are in urban districts of considerable population, so that, taking into account the nature and volume of the waste, there can be no doubt as to the desirability of admitting it to sewers wherever practicable.

A considerable number of tanneries, however, are situated in rural districts, where there are either no sewers or where the admixture of the tannery waste with the comparatively small volume of domestic sewage would very materially affect the treatment of the latter. In these cases, it is, in our view, necessary that the tanner should construct works for the thorough purification of the tannery waste, or else make a special contribution towards the purification of the mixed tannery waste and sewage.

Whether discharged into a river or a sewer, tannery waste may be specially objectionable apart from the question of organic pollution. Where realgar is used in the "unhairing" process, the waste may contain a large quantity of arsenic, and when foreign hides are dealt with, it may carry spores of anthrax. These points are referred to later.

Experiments made by the Massachusetts State Board of Health (Annual Report, 1909) and in the laboratory at Ealing have shown that the clarified liquor from mixed tannery waste is amenable to biological oxidation on filters.

Beyond these laboratory experiments, we have attempted no investigational work upon the purification of tannery waste. Such work is urgently called for, as much for the benefit of the trade as for that of rivers which are at present polluted with this waste.

We have visited a number of tanneries, however, and have had special samples of waste collected at typical yards for examination.

As showing the kind of crude waste liquors which are produced at various tanneries and the effluents obtained when these liquors are treated in tanks and straining filters, we may give some analytical figures relating to five tanneries and one leather dressing works.

Oak-Bark Tanning.

Tannery No. 60 may be cited as an example of oak-bark tanning.

At this tannery bullock skins, fresh from the slaughter house, are made into sole leather.

The skins are soaked first in water and then in strong milk of lime, before being "unhaired." The pelt is rinsed in water, tanned in a strong infusion of oak bark, and, finally, after drying, is polished and curried. The process takes, on the average, something like six or eight months to complete. The hair is sold to hair merchants.

The following figures obtained from chance samples indicate the character of the crude waste liquors produced at this tannery:

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* This is called "Hypo" (from hypo-sulphite, the older name for thiosulphate) in the trade.

TANNERY No. 60.

	Parts per 100,000.			
	No. 1. Soak water; chance sample drawn from soak tank.	No. 2. Lime liquor; chance sample drawn from 2nd lime pit.		No. 3. Spent tan liquor; chance sample drawn just before tank was run off.
Sample drawn	January 6th, 1913.	January 6th, 1913.		January 6th, 1913.
Sample analysed	January 8th, 1913.	January 8th, 1913.		January 8th, 1913.
Ammoniacal nitrogen	6·06	24·9		5·70
Albuminoid nitrogen	6·30	35·4		9·55
Total organic nitrogen	14·26	73·3		—
Total nitrogen (Kjeldahl)	20·32	98·2		—
Oxygen absorbed from N/8 permanganate at 80° F. at once	11·06	54·5		519·6
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	45·24	181·5		1,843·6
Hardness (as $CaCO_3$)	—	—		—
Hardness after boiling (as $CaCO_3$)	—	—		—
Total solids	338·0 $\left\{\begin{array}{l}211{\cdot}0\text{ V.}\\127{\cdot}0\text{ N.}\end{array}\right.$	1,564·0 $\left\{\begin{array}{l}753\text{ V.}\\811\text{ N.}\end{array}\right.$		3,178·0 $\left\{\begin{array}{l}2{,}474\text{ V.}\\704\text{ N.}\end{array}\right.$
Solids in suspension	—	371·0 $\left\{\begin{array}{l}63\text{ V.}\\308\text{ N.}\end{array}\right.$		—
Dissolved oxygen taken up from tap water at 65° F. in 48 hours	35·3	260·0		250·0
Dissolved oxygen taken up at 65° F. in 5 days	109·5	632·0		1,890·0
			Paper filtered sample.	
Caustic alkalinity (as H_2SO_4)	0·0	611·0	264·8	—
Alkalinity as Carbonate (as H_2SO_4)	—	149·3	129·0	—
Total alkalinity (as H_2SO_4)	43·0	760·3	393·8	—
Acidity (as H_2SO_4)	—	—		300·8 (litmus).
Fatty matter (extractable by ether)*	7·2	30·0		
Remarks	Deep brown-red liquor, containing some suspended matter. Foul smell.	Yellowish-green liquor, with much lime in suspension. Foul ammoniacal smell.		Reddish-brown liquor, with fine matter in suspension. Leathery smell.

* Most probably after acidification.

These figures require but little comment. They show that all three liquors are highly polluting. The soak liquor is about three times as strong as an average sewage, while the other two liquors are very much stronger.

The organic nitrogen figure for the lime liquor deserves notice, as indicating the very large quantity of organic nitrogenous matter in the liquor, which is a saturated solution of lime with much free lime in suspension.

At this tannery the liquids are discharged separately through a small detritus tank into the local sewers.

The total volume of waste liquor continually varies, according to the discharge of the various tanks or pits, but, on the average, it may be put at about 2,000 or 3,000 gallons per working day of ten hours. Of this volume the soak water represents something like one half and the lime and tan liquors one quarter each.

The average daily dry weather flow of the town sewage is about 2,750,000 gallons.

Various laboratory experiments were made in the purification of the waste from this tannery, which may be very shortly summarised :—

When equal volumes of spent lime liquor and spent tan liquor were mixed, and the very flocculent precipitate allowed to settle for two days, the supernatant liquid showed a purification of 37 per cent, as judged by the figure for "oxygen absorbed" in 4 hours (the actual "4 hours'" figures were 1,012 and 636). Subsequent precipitation of this settled liquid by alumino-ferric and lime gave a total purification of 55 per cent. on the original liquor.

The bubbling of air through the mixture of equal volumes of spent lime and spent tan liquors effected very little settlement of the resulting sludge. After diluting the mixture, however, with a nearly equal volume of water and again passing air through, a good settlement was effected.

When the clarified liquor was further diluted with water until the "4 hours'" figure was reduced to 170, and subjected to biological filtration, oxidation went on but slowly, 4 filtrations—at an average rate for the whole of 7·5 gallons per cube yard per 24 hours—reducing the "4 hours'" figure from 170·1 to 20·5, and the dissolved oxygen absorption in 5 days from 200 to 10.

It was subsequently found, however, that when a similarly clarified liquor was allowed to stand over sewage (*i.e.*, septic tank) sludge for 3 days, the 4 hours' "Oxygen absorbed" figure was reduced from 312·0 to 155·6. Further, this last liquor when diluted with an equal volume of water and passed three times through a biological filter, at an average rate (for the whole time) of 10·1 gallons per cube yard per 24 hours, gave an effluent of excellent quality. This is shown by the figures in the following table :—

Parts per 100,000.	Liquor as put on filter.	After first Filtration. Rate = 58 gallons per cubic yard per 24 hours.	After second Filtration. Rate = 16·4 gallons.	After third Filtration. Rate = 48·2 gallons.
Ammoniacal nitrogen	4·24	0·57	0·00	0·00
Albuminoid nitrogen	1·66	0·67	0·46	0·17
Nitric nitrogen	—	—	0·36	0·40
"Oxygen absorbed" in 4 hours	79·7	28·8	14·2	4·0
Dissolved oxygen taken up in 5 days	199·2	74·1	21·3	0·42
Incubator test	—	—	Putrid ; H_2S	Passed

Further experiments on the same lines gave confirmatory results.

The waste liquors from oak bark tanneries are thus capable of biological purification, but experiments on a practical scale are required.

Chrome Tanning.

Two examples of chrome tanning may be cited, one relating to goat skins and the other to calf skins.

(1) Tannery No. 61.

At this tannery foreign and colonial goat skins are made into glacé kid.

All the skins arrive in a dried or cured condition. They are soaked in water, painted on the skin side with a paste made of realgar and lime, and then unhaired. The unhaired pelts after having been soaked in milk of lime are bated in a liquor made up of dog-dung and water, and subsequently soaked, first in an acid solution of bichromate of potash, and then in a solution of sodium thiosulphate, after which they are dyed, fat-liquored and dressed.

The soak water, the spent chrome and thiosulphate waters, the bate water, the dye water, and the waste fat liquor, which together amount to about 125,000 gallons per working day of 14 hours, are discharged into settling tanks, four in number, where they are given either quiescent or continuous flow settlement.

The tank liquor is finally streamed through shallow filters, used in series, before being discharged.

There are in all eight filters, composed of coarse to medium clinker, and used in two series of four each. They are fed by means of perforated wooden troughs.

The lime liquors, which amount to about 25,000 gallons per working day, are sent into some very large soak-away ponds.

The following analytical figures will serve to indicate the nature of the crude waste from this tannery, as well as that of the tank liquor, the filter effluent and the sludge.

Tannery No. 61.

Parts per 100,000.

	No. 404. Soak water. Chance sample.	No. 406. Chrome water. Chance sample.	No. X. "Hypo" water. Chance sample.	No. 407. Spent Dye water. Chance sample.	No. 408. Mixed crude wastes (except Limes). Chance sample.	No. 409. Settled crude waste liquor (except limes), as passing into filter. Chance sample.	No. A. Filter effluent as flowing to brook. Chance sample.	No. B. Filter effluent as flowing to brook. Chance sample.	No C. Filter effluent as flowing to brook. Chance sample.	No. D. Filter effluent. Chance sample.	No. E. Settled tank liquor flowing to filters. Average sample taken every hour during a working day.	No. F. Filter effluent as flowing to brook Average sample taken every hour during a working day.	No. 405. "Lime water" as flowing to settling pond. Chance sample.	No. 410. "Lime water" as standing in 2nd pond. Chance sample.	No. 411. Mixed sludge from precipitation and lime tank. Chance sample.
Sample drawn	August 12th, 1913	August 12th, 1913.	August 12th, 1913.	August 12th, 1913.	August 12th, 1913.	August 12th, 1913.	August 12th, 1913.	October 2nd, 1913.	October 9th, 1913.	March 11th, 1914.	Feb. 5th, 1914.	Feb. 5th, 1914.	August 12th, 1913.	August 12th, 1913.	August 12th, 1913.
Sample analysed	August 20th, 1913	August 21st, 1913.	Sept. 11th, 1913.	August 21st, 1913.	August 19th, 1913.	August 19th, 1913.	August 19th, 1913.	October 7th, 1913.	October 10th, 1913.	March 13th, 1914.	Feb. 9th, 1914.	Feb. 9th, 1914.	August 20th, 1913.	August 20th, 1913.	Sept. 9th, 1913.
Ammoniacal nitrogen	5·84	—	—	0·11	6·80	3·45	3·64	2·84	2·06	1·40	1·92	1·99	4·04	6·90	*Parts per cent.* Moisture 62·4
Albuminoid nitrogen	5·64	—	—	1·04	4·02	3·30	1·54	1·34	1·27	2·25	2·31	1·90	15·70	3·40	Dry matter 37·6 { 2·9V. 34·7N. 100·0
Total organic nitrogen	13·56	—	—	3·20	9·82	7·68	4·02	2·05	2·23	3·59	5·02	3·84	42·56	6·56	—
Total nitrogen (Kjeldahl)	19·40	6·18	—	3·31	16·64	11·13	7·66	4·99	4·29	4·99	6·94	5·83	46·6	13·46	0·64 per cent. on the wet sludge.
Oxygen absorbed from N/8 permanganate at 80° F. at once	7·29	—	—	61·5	14·76	15·3	12·9	25·3	19·9 ‖	19·9 ‖	22·1	21·7	43·6	34·0	—
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	41·60	—	—	61·5	58·6	34·4	21·4	30·7	23·9	29·0	32·3	29·0	117·2	49·0	
Incubator test (by smell)	—	—	—	—	—	—	—	—	Failed ; H_2S.	Failed ; H_2S.	—	—	—	—	—
Hardness (as $CaCO_3$)	—	—	—	—	—	—	—	—	—	—	—	37·5	—	—	—
Hardness (after boiling)	—	—	—	—	—	—	—	—	—	—	—	35·2	—	—	—
Total solids	1568·0 { 134·0 V. 1434·0 N.	1269·0 { 140·0 V. 1129·0 N.	— —	559·0 { 98·0 V. 461·0 N.	346·0 { 117·0 V. 229·0 N.	395·0 { 105·0 V. 290·0 N.	814·0 { 55·0 V. 759·0 N.	— —	— —	— —	— —	— —	†1307·0 { 150·0 V. 1157·0 N.	332·0 { 82·0 V. 250·0 N.	— —
Solids in suspension	33·8 { 17·8 V. 16·0 N.	50·0 { 32·0 V. 18·0 N.	29·7 { 28·1 V. 1·6 N.	36·0 { 34·0 V. 2·0 N.	111·0 { 54·0 V. 57·0 N.	69·0 { 32·0 V. 37·0 N.	26·3 { 17·5 V. 8·8 N.	— —	— —	11·4 { 6·0 V. 5·4 N.	20·8 { 10·8 V. 10·0 N.	10·4 { 4·8 V. 5·6 N.	†1677·0 { 12·0 V. 1665·0 N.	15·4 { 14·0 V. 1·4 N.	— —
Dissolved oxygen taken up from tap water at 65° F. in 48 hours	63·3	—	—	—	48·0	32·0	19·1	8·3	13·7	15·0	22·0	10·8	75·2	45·0	—
Dissolved oxygen taken up at 65° F. in 5 days	121·8	—	—	5·1 (?)	87·7	45·4	38·5	29·1	28·8	33·5	54·0	29·9	102·8	79·6	—
Caustic alkalinity (as H_2SO_4)	0·0	—	Slightly acid to litmus on Sept. 11th	Very slightly acid.	20·4	5·1	Trace.	Trace.	0·0	—	—	6·6	977·6	0·0	—
Total alkalinity (as H_2SO_4)	54·3	—	—	—	67·9	44·1	37·4	36·7	35·3	—	—	32·9	1059·2	67·9	—
Arsenic (As)	3·34	0·30	Not estimated.	0·023	0·70	0·43	0·38	—	—	—	—	—	24·3	1·22	0·99 per cent. on the wet sludge.
Potassium bichromate ($K_2Cr_2O_7$)	—	523·0 (Sept. 2nd)	—	—	—	—	—	—	—	11·1	—	—	—	—	—
Chromium sesquioxide (Cr_2O_3)	—	—	—	—	—	—	—	—	—	0·56	—	—	—	—	—
Sodium thiosulphate ($Na_2S_2O_3$)	—	—	2060·0	—	—	—	1·0	Not estimated.	35·5	52·6 approx.*	31·7	37·2	—	—	—
Remarks	Brown turbid liquid, with brown solids and some hair in suspension. Putrid smell.	Orange coloured solution of potassium bichromate, with yellow solids in suspension. Soapy smell.	Greenish coloured solution, with some suspended matter.	Dark green solution, with a good deal of suspended matter. No smell.	Brown turbid liquor, with much brown suspended matter. Foul smell, conjoined with an odour of napthalene.	Brownish turbid liquor, with much suspended matter. Foul smell, with some napthalene odour.	Brown turbid liquor, with a good deal of suspended matter. Foul smell, with H_2S. This effluent contained no chromium salt on Sept. 5th.	Yellowish turbid liquor, with moderate quantity of suspended matter. Foul smell, with slight napthalene odour. Note.—The low ratio of the "oxygen absorbed" at once to that in 4 hours, is due to the presence of thiosulphate.	Yellowish turbid liquor, with much suspended matter. Foul smell, and odour of napthalene.	Yellow, and with a faint smell resembling phenol, although no trace of this compound could be found.	Brown-yellow turbid liquor. Considerable fine and coarse suspended matter. Usual foul tannery smell; also smell of napthalene. Little H_2S.	Bright greenish-yellow. Small amount of suspended matter. Slight foul tannery smell. Very little H_2S.	Thick milky liquor, with much limey suspended matter. Foul smell. A good deal of hair in suspension.	Yellowish - green liquid, with some finely divided suspended matter. Foul smell, with much H_2S.	This sludge consisted mainly of lime and lime salts. No heavy metal excepting arsenic was found in it.

* Titrated in neutral or faintly alkaline solution, because of the chromate present.

† This discrepancy probably due to difficulty of sampling.

‖ These high figures (and no doubt the corresponding figures in the two preceding samples of effluent) are largely due to the "Hypo" present.

All the above liquors and effluents are obviously very polluting in character. The least polluting, the waste dye water, would rank with a somewhat weak domestic sewage, while the final effluent from the purification of the mixed wastes without the lime liquor is considerably stronger.

The special points to be noted are (1) that all the liquors contain arsenic, some in very large amount; and (2) that the waste chrome and "Hypo" liquors still contain a very large quantity of bichromate and thiosulphate, respectively.

The final effluent, drawn on 12th August, 1913, contained 0·38 part of arsenic per 100,000, the lime water standing in the soak-away ponds 1·22 parts, and the sludge 0·99 per cent (= 2·6 per cent. on the dry matter).

f. A. R. ushny, 4031, *et* *eq.*

We have taken some evidence on the question whether quantities of arsenic such as these may with safety be sent into streams, allowed to mix with subsoil water, or be spread over land, but it does not warrant us in expressing an opinion on the question. The matter is one which requires experimental investigation.

As regards the bichromate and the thiosulphate, it would seem that the discharge of liquors containing such large quantities of these substances must be very wasteful, and that some at least of this loss might be avoided by re-use of the liquors or by recovery of the valuable substances contained in solution.

The total volume of waste liquor discharged per working day of 10 hours is about 15,000 gallons on the average, 10,000 gallons comprising the mixed liquor which is treated in the settling tanks and on the filters, and 5,000 gallons flowing as lime water to the large soak-away ponds.

The filtration of the settled waste, as carried out at these works, only has the effect of removing some suspended matter. The rate of filtration is so high as to preclude the possibility of effective biological purification, and the method of applying the waste to the filter is very ineffective.

Since the filtering material has to be renewed somewhat frequently, it would seem that the money spent in this way might be better applied in obtaining good precipitation and settlement of the suspended impurities contained in the liquors.

One filtration of the filter effluent* of October 2nd, 1913, through a small matured laboratory filter, at the rate of 53·5 gallons per cube yard per 24 hours, and one filtration of the effluent of October 9th,* at the rate of 33·6 gallons, yielded filter effluents yellowish in colour but almost clear, and with a slight earthy smell. The second effluent was siphoned from its deposited solids before being put on to the filter.

The following figures of analysis show the purification thus effected :—

Parts per 100,000.	Original effluent of October 2nd.	Effluent after biological filtration.	Original effluent of October 9th.	Effluent after biological filtration.
Ammoniacal nitrogen	2·84	1·01	2·06	1·18
Albuminoid nitrogen	1·34	0·22	1·27	0·26
Total organic nitrogen	2·05	1·91	2·23	1·80
Nitrous nitrogen	—	0·0	—	0·0
Nitric nitrogen	—	0·30	—	0·36
Total nitrogen (Kjeldahl)	4·99	3·22	4·29	3·33
"Oxygen absorbed from N/8 permanganate at 27° C. at once	25·3	17·9	19·9	15·5
"Oxygen absorbed" from N/8 permanganate at 27° C. in 4 hours	30·7	18·9	23·9	16·7
Dissolved oxygen taken up at 18° C. in 5 days	29·1	13·1	28·8	11·4
Incubator test	—	Passed (slight earthy smell).	Failed; H_2S.	Passed (slight earthy smell).

* Neither of these effluents contained liquor from the lime pits.

The effluents contained thiosulphate (but no chromium), though the amount present was not estimated in the first sample. An approximate measure of it is given, however, in the difference between the figures for "oxygen absorbed" at once and in 4 hours.

The foregoing figures indicate the oxidation in the biological filter of much of the organic matter present in the original effluent, but of only a small proportion of the thiosulphate, most of which still remained in the filtered liquid. Further laboratory experiments, to be followed by experiments on the large scale, are required.

(2) Tannery No. 62.

Calf skins only are dealt with here. They are obtained fresh from the slaughter-house, and are converted into shoe leather, the hair being sold for manufacture into rugs, blankets, yarn, etc.

The process is as follows:

The skins are

(1) Soaked in water;
(2) Steeped in milk of lime containing realgar;
(3) Unhaired.

The pelts are

(4) Steeped in a liquor containing lime and sulphide of sodium;
(5) Scraped;
(6) Washed in a revolving drum with running water;
(7) Dipped in a solution of acetic acid;
(8) Rinsed with water;
(9) Drummed in a reduced solution of bichromate of potash and sulphuric acid for 5 or 6 hours;
(10) Washed, dried, dyed, and finally finished.

With the exception of the lime liquors, which are settled separately, the waste liquors are mixed together and discharged into the river, after passing through five rough settling-ponds used in series. The total volume of waste liquor amounts to something like 12,000 gallons per working day of 10 hours, and the total capacity of the settling-ponds is about 24,000 gallons.

The following figures relate to some chance samples drawn in September, 1913. They give a general idea of the character of the waste liquors produced and of the effluent discharged.

TANNERY No. 62.

Parts per 100,000.	No. 1 K. Soak water from stirred-up tank. Chance sample.	No. 2 K. "Lime water" from stirred-up tank, when at its strongest. Chance sample.	No. 4 K. Lime and sodium-sulphide water from stirred-up tank, which had been in use for 20 hours. Chance sample.	No. 3 K. Drum wash water taken at mid-flow. Chance sample.	No. 8. Acid wash water. Chance sample.	No. 7 Waste chrome liquor. Chance sample.	No. 6. Waste dye liquor. Chance sample.	No. 5 K. Mixed settled effluent as discharged. Chance sample.	No. 6 K. Sludge. Chance sample.
Sample drawn	Sept. 9th, 1913.	Sept. 9th, 1913.	Sept. 9th, 1913.	Sept. 9th, 1913.	Sept. 14th, 1913.	Sept. 14th, 1913.	Sept. 14th, 1913.	Sept. 9th, 1913.	Sept. 9th, 1913.
Sample analysed	Sept. 11th, 1913.	Sept. 16th, 1913.	Sept. 11th, 1913.	Sept. 11th, 1913.	Sept. 17th, 1913.	Sept. 18th, 1913.	Sept. 17th, 1913.	Sept. 11th, 1913.	Jan. 23rd, 1914.
Ammoniacal nitrogen	2·62	8·37	5·40	0·51	0·39	0·36	0·03	2·50	
Albuminoid nitrogen	3·20	9·68	9·50	0·68	3·44	0·67	0·08	4·86	*Parts per cent.* Moisture 8·6
Total organic nitrogen	—	21·79	14·70	2·10	6·69	3·11	0·19	11·20	Dry matter 91·4 { 10·6 V. 80·8 N.
Total nitrogen (Kjeldahl)	(?)	30·16	20·10	2·61	7·08	3·47	0·22	13·7	100·0
Oxygen absorbed from N/8 permanganate at 80° F. at once	2·45	59·3	74·1	2·45	6·09	—	1·98	20·0	
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	10·5	114·7	97·6	5·52	20·14	—	3·16	42·0	
Hardness (as $CaCO_3$)	—	—	—	—	305·8	—	—	230	This sludge consisted almost entirely of carbonate of lime and contained only 0·24 per cent. of phosphoric acid (P_2O_5). Nitrogen was not estimated.
Hardness (after boiling)	—	—	—	—	—	—	—	228	
Total solids	644·4 { 74·0 V. 570·0 N.	1833·0 { 105·0 V. 1728·0 N.	748·8 { 117·6 V. 631·2 N.	85·6 { 34·8 V. 50·8 N.	449·2 { 234·0 V. 215·2 N.	9590·0 { 1872·0 V. 7718·0 N.	44·4 { 13·2 V. 31·2 N.	642·0 { 111·6 V. 530·4 N.	
Solids in suspension	14·2 { 13·4 V. 0·8 N.	657·0 {	143·6 { 132·8 V. 10·8 N.	23·0 { 14·8 V. 8·2 N.	10·8 { 10·8 V. 0·0 N.	46·0 { 36·0 V. 10·0 N.	1·0 { 1·0 V. 0·0 N.	42·2 { 14·8 V. 27·4 N.	
Dissolved oxygen taken up from tap-water at 65° F. in 48 hours	14·6	21·4	30·1	7·4	80 + x	4·0	0·40	13·6	
Dissolved oxygen taken up at 65° F. in 5 days	25·0	109·2	83·8	13·2	147·0	28·0	0·40	38·2	
Acidity (as H_2SO_4)	—	—	—	—	86·7	1378·0	—	—	
Caustic alkalinity (as H_2SO_4)	0·0	938·6	398·0	0·0	—	—	0·0	203·0	
Total alkalinity (as H_2SO_4)	27·2	1017·4	476·0	18·0	—	—	51·6	239·0	
Arsenic (As)	0·08	19·8	1·52	0·13	0·30	0·08	0·03	2·13 (Oct. 1st, 1913:—0·68 of this arsenic was in solution.)	0·43 per cent. in sludge, containing 8·56 per cent. moisture. No copper, lead, antimony, or tin was present.
Remarks	Reddish - brown liquor, with strong unpleasant smell. Some fairly well aggregated solids.	Thick limey liquor, with considerable admixed organic matter—hairs, etc. Foul ammoniacal smell.	No notes were made on this sample.	Reddish brown liquor, with some well aggregated solids. No smell.	Turbid greyish liquor, with some suspended matter. Acetic acid smell.	Dark green liquor, with considerable amount of suspended matter. Sour putrid smell. A second chance sample of waste chrome liquor, drawn and examined early in October, 1913, was found to contain in solution 0·91 per cent. of chromium sesquioxide, Cr_2O_3 (= 910 parts per 100,000.)	Violet - black liquid, with very little suspended matter. Neutral to litmus. No smell.	Turbid liquor, with greyish white solids. N.B.—This liquor did not contain any dye or chrome waste, and only part of the drum wash water.	

The above figures resemble those relating to Tannery No. 61, and therefore require little comment.

The final effluent as discharged was in several respects considerably stronger than average domestic sewage, and it contained 2·13 parts of arsenic per 100,000.

All the crude liquors contained arsenic, mostly in small or minute quantity, but the lime water contained 19·8 parts per 100,000. The sludge, which was comparatively dry and probably did not contain half its weight of water, had 0·43 per cent. of arsenic.

Alum Tanning.

Tannery No. 63.

Sheep skins from Australia and the Cape are made into glove leather at this mill. The wool is sold to woollen manufacturers.

The skins are soaked in water, painted with lime and sodium sulphide, and unhaired. After the wool has been removed and sorted, the pelts are thrown into tanks containing milk of lime and sodium sulphide, rinsed with water, bated with artificial bate, and drenched. After drenching, they are either tanned with alum, white of egg and salt, in a revolving drum, or with oak bark in a vat, according to the class of skin dealt with. The tanned skins are dried and finished.

There is practically no waste from the alum tanning itself, and the lime pits are only run off very occasionally, so that the wastes comprise soak water, lime wash water, bate water, drench water, oak-bark tan liquors and dye water.

The soak water and the lime wash water together constitute the great bulk of the total volume of the waste. The whole of the waste is discharged as produced into the local sewers, through a small grit chamber fitted with a grid.

The following analyses relate to chance and average samples from this mill.

TANNERY, No. 63

Parts per 100,000.

	No. 412. Soak water from pits which receive Cape skins. Chance sample.	No. 413. Soak water from pits which receive Australian skins. Chance sample.	No. 416. Wash water from pits which receive the sulphide painted skins (contains sodium sulphide). Chance sample.	No. 414. Lime wash water from pit in which pelts are finally rinsed. Chance sample.	No. 415. Spent water from tan and dye vats. Chance sample.	No. 417. Mixed screened liquor as flowing to river. Average of 18 samples taken from 12 noon to 5 p.m. in equal quantities.
Sample drawn	Sept. 25th, 1913.	Sept. 25th, 1913.	Sept. 25th, 1913.	Sept. 25th, 1913.	Sept. 25th, 1913.	Sept. 25th, 1913.
Sample analysed	Sept. 29th, 1913.	Sept. 30th, 1913.	Sept. 26th, 1913.	Sept. 29th, 1913.	Sept. 30th, 1913.	Sept. 26th, 1913.
Ammoniacal nitrogen	1·88	2·70	0·37	2·88	0·63	2·88
Albuminoid nitrogen	1·46	1·28	2·32	4·54	0·99	4·94
Total organic nitrogen	3·67	3·24	6·28	11·08	1·10	10·48
Total nitrogen (Kjeldahl)	5·55	5·94	6·65	13·96	2·24	13·36
Oxygen absorbed from N/8 permanganate at 80° F. at once	5·21	5·14	18·3	7·91	141·1	17·14
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	20·11	16·35	32·8	25·64	342·8	57·22
Total solids	256·8 { 78·4 V. 178·4 N.	143·6 { 61·2 V. 82·4 N.	490·8 { 72·4 V. 418·4 N.	438·4 { 48·8 V. 389·6 N.	461·6 { 391·6 V. 70·0 N.	562·8 { 194·0 V. 368·8 N.
Solids in suspension	91·2 { 38·4 V. 52·8 N.	37·2 { 17·0 V. 20·2 N.	228·4 { 37·6 V. 190·8 N.	195·6 { 70·4 V. 125·2 N.	10·4 { 10·4 V. 0·0 N.	173·2 { 64·8 V. 108·4 N.
Dissolved oxygen taken up from tap water at 65° F. in 48 hours	35·2	21·9	26·0	10·8	22·0	56·4
Dissolved oxygen taken up at 65° F. in 5 days	53·6	47·0	35·0	33·0	73·0	78·0
Acidity (as H_2SO_4), using Phenol-phthaleïn	—	—	—	—	* 140·0 (?)	—
Caustic alkalinity (as H_2SO_4)	0·0	0·0	272·3	308·1	—	35·8
Total alkalinity (,, ,,)	54·46	49·44	290·2	358·3	—	116·4
Arsenic (As)	0·02	0·21	0·07	0·05	0·00	0·04
Potash (K_2O)	17·9	—	—	—	—	—
Remarks	Brown liquor with much fine brown suspended matter. Foul smell. Alkaline.	Brown liquor with fine brown suspended matter. Foul smell. Alkaline.	Greenish - yellow liquid with much lime and other suspended matter. Foul smell.	Thick greyish liquor with much, lime, etc. in suspension. Foul smell.	Deep reddish-brown liquid with small quantity of suspended matter. Smell of glue. Acid reaction.	Reddish-brown turbid liquor, with strong putrid smell.

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* End point obscured by dye,

The crude liquors from this tannery (No. 63) are, on the whole, not so strong as those from the tanneries mentioned previously, but they are nevertheless highly polluting.

The mixed liquor as flowing to the sewer was two or three times as strong as an average sewage. It contained 173·2 parts per 100,000 of suspended matter, and took up 57 parts of oxygen from permanganate in 4 hours and 78·0 parts of dissolved oxygen in 5 days. It was also strongly alkaline.

Oil Tanning.

Tannery No. 64.

At this tannery sheep skins from the home market are made into chamois leather and hat leather.

The raw material consists partly of the skins of freshly-killed sheep and partly of limed pelts from the fellmongers.

The fresh skins are soaked in water, painted with lime and sodium sulphide, and then unhaired. After this the pelts are soaked for some time in limed pits.

The limed pelt from either source is split into two parts, the outer part of the pelt with the grain being tanned with sumach and dyed brown for hat linings, etc., and the inner part being treated with cod liver oil for chamois leather.

In the oil tanning process the pelts, after being oiled, are pummelled by machinery and hung up in a warm room, this process being repeated as often as is necessary. When thoroughly tanned, they are washed in a solution of carbonate of soda, to remove any excess of oil, and finally dried off. The only waste liquor from this part of the process is the spent soda solution, and this is small in volume.

The bulk of the waste liquor from the tannery consists of soak water, milk of lime, and dye water, with the partially spent liquor from the sumach tanning vats.

The whole of the liquid waste from the tannery, representing a volume of about 10,000 gallons per working day of 9¼ hours, gravitates to an underground sump (capacity 16,400 gallons), whence it is pumped slowly to the straining filters.

The sump is sludged once a week, and the sludge is lagooned until dry enough to be carted away.

There are in all four filters, two primary beds, and two secondary beds. They are filled with coarse clinker to a depth of 3 feet 6 inches, and are used in pairs on alternate days as straining filters. The total cubic content of the four filters is 980 cubic yards.

The filter effluent is discharged into a small stream.

The figures given in the table following this page relate to chance samples drawn at this tannery.

Tannery No. 64.

Parts per 100,000.

	No. 399. Soak water from pit, just about to be run off. Chance sample.	No. 400. Lime and sodium sulphide liquor. Chance sample.	No. 402. Waste tan liquor from sump which receives contents of sumach vats. Chance sample.	No. 395. Dye waste as flowing to drain. Chance sample.	No. 396. Waste from sump in oil mill. Chance sample.	No. 401. Mixed and settled waste from sump. Chance sample.	No. 403. Filter effluent as leaving secondary filter for stream. Chance sample.
Sample drawn	July 24th, 1913.	July 24th, 1913, 3.30 p.m.	July 24th, 1913, 4.0 p.m.	July 24th, 1913, 11.30 a.m.	July 24th, 1913.	July 24th, 1913, 3.45 p.m.	July 24th, 1913, 4.30 p.m.
Sample analysed	August 5th, 1913.	August 6th, 1913.	July 30th, 1913.	July 30th, 1913.	August 5th, 1913.	July 29th, 1913.	July 29th, 1913.
Ammoniacal nitrogen	10·92	30·2	1·05	0·36	0·28	3·00	1·65
Albuminoid nitrogen	4·62	100·0 approx.	3·75	1·48	1·45	2·18	1·93
Total organic nitrogen	12·34	223·9	6·85	2·35	3·51	3·96	3·81
Total nitrogen (Kjeldahl)	23·26	254·1	7·90	2·71	3·79	6·96	5·46
Oxygen absorbed from N/8 permanganate at 80°F. at once.	25·1	159·6	301·2	20·5	43·3	9·0	7·5
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	75·8	514·0	1043·6	34·2	131·1	30·8	31·7
Hardness (as $CaCO_3$)	—	—	—	—	—	—	57·1
Hardness (after boiling)	—	—	—	—	—	—	50·0
Total solids	1038·0 { 317·6 V. 720·4 N.	2783·0 { 1720·0 V. 1063·0 N.	1144·0 { 957·6 V. 186·4 N.	188·0 { 88·0 V. 100·0 N.	2129·6 { 824·8 V. 1304·8 N.	300·8 { 98·0 V. 202·8 N.	234·8 { 100·4 V. 134·4 N.
Solids in suspension	137·2 { 53·2 V. 84·0 N.	483·0 { 203·0 V. 280·0 N.	184·4 { 160·8 V. 23·6 N.	85·6 { 56·8 V. 28·8 N.	75·2 { 75·2 V. 0·0 N.	32·0 { 24·8 V. 7·2 N.	32·4 { 15·6 V. 16·8 N.
Dissolved oxygen taken up from tap water at 65° F. in 48 hours	114·0	255·0	108·0	0·0	47·0	18·8	28·0
Dissolved oxygen taken up at 65° F. in 5 days	202·0	725·0	558·0	18·5*	82·0*	64·0‖	87·2‖
Total acidity (as H_2SO_4)	—	—	—	—	686·0	—	—
Acidity after boiling („ „)	—	—	—	—	586·1	—	—
Caustic alkalinity (as H_2SO_4)	0·0	896·3	Neutral.	Neutral.	—	0.0	48·8
Total alkalinity („ „)	239·0	1276·5	62·5	Neutral.	—	51·6	73·3
Fatty matter (extractible by ether)	—	—	—	—	306† { 286 V. 20 N.	—	—
Arsenic (As)	0·09	0·08	Not estimated.	0·00	0·046	0·00	0·00
Remarks	Brown liquid, with much glutinous suspended matter. Foul smell.	Greenish - yellow liquid, with much limey suspended matter. Strong foul smell.	Brown liquid, with much suspended matter which settled quickly. Strong tan smell.	Reddish - brown liquid, with a good deal of suspended matter. Faint aromatic smell.	Yellowish liquor, with much greasy matter in suspension. Unpleasant oily smell. Strongly acid.	Reddish - brown liquid, containing a good deal of coarse brown matter, which settled quickly. Strong foul smell.	Brown liquor, with a good deal of suspended matter. Foul smell.

* 6 days. † Approximate figure. ‖ 7 days.

These figures deserve notice, in that they show clearly how the strong lime water and the soak water from a tannery of this class are the chief factors in determining the general character of the waste.

The waste tan liquor is very strong in oxygen absorbing power, but its volume is small in comparison with the soak and lime waters, and no doubt it is largely precipitated by the lime water in the general sump. It is clear that a very large amount of tanning material is run away in this waste tan liquor.

Very considerable settlement and removal of suspended matter evidently takes place in the sump, but the filters appear to do little or no work. They were badly clogged with suspended matter at the time the samples were taken, and they must necessarily clog up very rapidly when called upon to treat a liquor containing over 30 parts of suspended matter per 100,000.

It would appear that the money expended on these filters might have been better applied to tank construction.

A chance sample of sludge, No. 398, from the larger settling tank at this tannery, drawn along with the other samples and afterwards kept in ice for 6 weeks, gave the following figures on analysis:

	Per cent.
Moisture	84·5
Dry matter	15·5
	100·0
Matter volatile on ignition	7·94
Matter non-volatile	7·56
	15·5

		Calculated on the dry matter. Per cent.
Nitrogen	0·29	1·87
Phosphoric acid (P_2O_5)	0·027	0·17
Oxide of iron and alumina	0·40	—
Lime (CaO)	3·67	23·7
Magnesia	0·17	—
Arsenic (As)	0·0	—
Copper, lead, antimony, tin	absent.	

This sludge contained practically no phosphate, but, on the other hand, it was free from arsenic. Apart from the question of anthrax, it would have a small manurial value, mainly because of the nitrogen and lime present.

Leather Dressing.

Leather dressing is an industry allied to tanning which has of late years developed rapidly in this country. It may be briefly described as the re-tanning, dyeing and dressing of lightly tanned hides, from India and the East, for sale in particular markets at home and abroad.

Tannery No. 65 may be cited as an example of the trade.

Cow hides and sheep skins from India and foreign goat skins are made by the firm into all kinds of "upper" leather for boots and shoes. All the hides, as bought by the firm, have been already tanned, or partially tanned, with vegetable tannage.

The hides are first softened in water and then worked in a revolving drum, first with warm soda solution, to remove dirt and some of the vegetable tannage, and then in dilute sulphuric acid (0·5 per cent. by weight of the wet skins), to remove stains.

The cleaned skins are next tanned in a paddle bath with sumach, and then dyed in colours ranging from light yellow to purple and black. Finally they are dried, curried, shaved, stained, glazed, artificially grained and finished.

Waste liquors are produced from the drumming with soda and acid, from the tanning bath, and from the dyeing. They are sent direct into the public sewers through a small catch pit.

The following figures indicate the general character of the various crude liquors produced at this tannery.

TANNERY No. 65.

Parts per 100,000.

	No. 1. Soda waste water. Chance sample.	No. 2. Acid waste water. Chance sample.	No. 3. Waste tan (sumach) water from paddle bath. Chance sample.†	No. 4 Black dye waste from drum. Chance sample.	No. 5. Brown dye waste from paddle bath. Chance sample.	No. 6. Mixed general waste flowing to sewers. Average of 6 half-hourly samples.
Sample drawn	October 24th, 1913.	October 24th, 1913.	October 24th, 1913.	October 24th, 1913.	October 24th, 1913.	October 24th, 1913.
Sample analysed	October 27th, 1913.	October 28th, 1913.	October 29th, 1913.	October 29th, 1913.	October 28th, 1913.	October 27th, 1913.
Ammoniacal nitrogen	0·33	2·65	—	0·18	0·12	1·08
Albuminoid nitrogen	4·96	5·94	—	6·52	1·56	2·97
Total organic nitrogen	11·19	13·72	—	17·47	3·72	6·37
Total nitrogen (Kjeldahl)	11·52	16·37	45·9	17·65	3·84	7·45
Oxygen absorbed from N/8 permanganate at 80° F. at once	494·9	426·0	—	221·6	115·7	116·1
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	979·2	717·6	1244·3	715·4	224·5	348·0
Hardness (as $CaCO_3$)	—	—	—	—	—	—
Hardness (after boiling)	—	—	—	—	—	—
Total solids	1614·4 { 1045·2 V. 569·2 N.	2155·6 { 747·6 V. 1408·0 N.	2784·0 { 2210·0 V. 574·0 N.	2257·0 { 1057·0 V. 1200·0 N.	770·4 { 405·6 V. 364·8 N.	1090·4 { 510·8 V. 579·6 N.
Solids in suspension *	—	—	—	—	—	—
Dissolved oxygen taken up from tap-water at 65° F. in 48 hours	220·0	157·0	77·0	130·0	?	119·0
Dissolved oxygen taken up at 65° F. in 5 days	256·0	307·0	298·0	222·0	38·5	139·5
Acidity (as H_2SO_4)	—	814·8§	251·2‖	—	312·3‖	—
Alkalinity (as H_2SO_4)	203·7	—	—	—	—	27·2¶
Remarks	Dark brown liquid, containing much suspended matter. Very little smell.	Brown liquid, containing much suspended matter. Slight smell of vegetable tan.	Yellowish - brown liquid, with very large quantity of brown suspended matter. Strong sweet smell of sumach.	Reddish-black liquid, with large amount of flocculent black suspended matter. Sweetish smell.	Reddish - brown liquid, with large amount of suspended matter. Practically no smell.	Black liquid, with much suspended matter. Sweet smell of sumach.

*NOTE.—All the liquors contained large quantities of suspended matter, and the tan liquor a very large quantity. It was found impossible to estimate this suspended matter satisfactorily, as its sticky character made it exceedingly difficult to filter off.

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† Owing to the excessive amount of suspended matter in this sample, the figures given are to be regarded as approximate only.

§ After boiling. This figure is only an approximation. ‖ After boiling. ¶ Approximate.

A glance at the above figures will suffice to shew that these waste liquors from a leather-dressing works are very like those from a tannery. The important difference is that there is in the case of the leather-dressing no *ordinary* soak water or lime liquor. With the exception of the soda waste, they were either acid or neutral, while the general waste was slightly alkaline.

All of them gave high figures for albuminoid nitrogen and for oxygen absorbed from permanganate, and they all contained very large quantities of suspended matter.

Except in the case of the brown dye waste, all the liquors also gave very high figures for dissolved oxygen absorption in 48 hours and 5 days.

The figures for total nitrogen ranged from 3·84 to 45·9 parts per 100,000.

The waste liquors from this particular works are sent into the public sewers. Good clarification of the mixed liquors from a leather-dressing works would undoubtedly result in a much less polluting liquor than clarified tannery waste. Still, it is obvious that such liquors should be classed along with tannery waste liquors as being far too polluting for discharge into streams without purification.

Summary as regards Tannery Waste.

Some of the waste liquors from tanneries, notably the lime waters, must rank as amongst the most polluting of liquid trade wastes. The lime waters are usually saturated solutions of lime, with much lime and carbonate of lime in suspension; they contain a very large quantity of dissolved nitrogenous and other organic matter, and they possess a most offensive smell.

Mixed with the other liquors from a tannery, these lime liquors throw down much of the suspended matter and the dissolved tanning substances in the form of a copious and slow-settling precipitate.

The soak waters and the so-called spent tan liquors are also highly polluting.

The crude mixed waste liquor from a tannery varies much in strength from hour to hour, and it differs to some extent at every yard, but its average strength may be taken at three or four times that of normal domestic sewage.

In addition to its organic strength, such waste may, and frequently does, contain a considerable quantity of arsenic or chromium, or both, and when foreign hides are dealt with, spores of anthrax as well.

Laboratory experiments have shown that after clarification it is amenable to biological purification ; but, so far as we are aware, no example of such treatment on a working scale exists at the present time in this country. There is no doubt that it could also be treated by filtration through land, but a considerable area of suitable soil would be necessary for satisfactory purification. Serious nuisance from smell would be likely to arise if the land were not rested frequently.

The presence of any considerable proportion of untreated tannery waste in domestic sewage has been held, probably with justification, to render the sewage more difficult to treat; and certainly it must increase the responsibility of the sewer authorities receiving it, not only on account of the arsenic and the anthrax spores which it may contain, but also because of the possible silting up of sewers through the discharge into them of strong unsettled lime waters.

Nevertheless, we are of opinion that tannery waste should, subject to proper safeguarding of the sewerage system, be taken into sewers wherever practicable, on the grounds that owing to its offensive character it ought never to be treated by itself in the neighbourhood of dwelling houses, and that its treatment when diluted with sewage will prove more economical than treatment by itself.

A number of cases could be cited as showing that when it is present in small proportion to the sewage no serious difficulties arise at the local sewage works.

When tannery waste is produced in rural districts it is necessary that it should be adequately purified before being discharged into streams.

By mixing all the crude liquors together and settling in tanks, which are cleaned out frequently, it can be considerably improved in quality. This process involves the production of a large quantity of sludge, which may in some cases contain anthrax spores and a large amount of arsenic. The purification of the liquid portion of the waste, either on land or on filters, has not yet been thoroughly investigated, and is a matter for further consideration.

From the few laboratory experiments which we have made, we should infer that it would probably be practicable to purify most tannery wastes so as to produce an effluent containing not more than 4 parts of suspended solids per 100,000, and taking up not more than 4 parts of dissolved oxygen in 5 days.

We may conclude this summary by pointing out that the tanner frequently sends to waste very large quantities of valuable tanning material. We feel sure that in this and other respects methods of working could be much improved, to the benefit of the trade itself, as well as of the rivers and streams into which the waste liquors are discharged.

The Dairy Industry.

87. The dairy industry has been extending rapidly of late years, and the development seems likely to continue. In Ireland alone there are at the present day some 800 creameries and cream-separating stations, most of them situated in rural districts. There are also a large number of dairies in England and Scotland, but we have been unable to obtain exact data with regard to their number, etc.

The chief branches of the dairy industry comprise butter-making, cream-separating, cheese-making, and the production of condensed milk.

At creameries, where butter is manufactured, the cream is separated from the fresh milk which the neighbouring farmers bring in. At cream-separating stations the milk is weighed and strained, after which it is heated to 120° F. or over, and separated by means of a centrifuge, the cream being subsequently cooled and sent in cans to be churned. In both cases the separated milk is returned to the farmers.

At butter factories various butters made at farms are received and blended. At other centres condensed milk and cheese are made.

Liquid wastes are produced from creameries, cream-separating stations, and centres where cheese-making is carried on. These are highly polluting liquids.

Large volumes of water are used for cooling milk, cream, etc, but these are practically clean waters, and can be disposed of with the rain water in the ordinary way.

The polluting liquids comprise the washings from the various apparatus—such as separators, coolers, butter-workers, churns, tanks—used for holding "whole" milk, cream, separated milk, buttermilk and whey, together with rinsings from milk cans and water from the washing down of floors. The combined wastes resemble milky water. The strongest liquid is that derived from the washings of the butter and the butter-workers.

The nature of these mixed liquids may be seen by referring to the following figures of analysis, handed in by Mr. Walter Thorp, F.I.C., of Dublin, as being typical of strong dairy wastes:—

	Parts per 100,000
Total solids	620
Suspended solids	236
Dissolved solids	385
Ash in dissolved solids	96
Ash in suspended solids	16·6
Total ash	112·6
Dissolved organic matter	289
Suspended organic matter	218·4
Total organic matter	507·4
Nitrogen in suspended matter	26·32
Nitrogen in soluble matter	12·40
Total nitrogen	38·72
Total chlorine in solution	19·25
Equal to sodium chloride	31·9

The flow of waste liquids from a creamery fluctuates considerably during the day, and the liquor also varies in composition, both hourly and daily. Further, the flow of liquid wastes is much greater at certain seasons of the year than at others. During the months of June, July and August, the dairying industry is at its height, and the volume of waste waters is at a maximum; in winter it is at a minimum.

The volume of polluting liquid wastes from a creamery or cream-separating station varies largely in individual cases, according as the water supply is ample or the reverse.

Generally speaking, it may range from about one-third to five-sixths of the total volume of milk treated daily, a medium-sized creamery dealing with something like 2,000 gallons of milk per day in summer,

Butter-making.

After the cream has been separated from the milk it is cooled and soured, sometimes with the addition of a biological culture known as a "starter"; it is churned when at the proper temperature—about 57° F. in Summer and 60° F. in Winter, the buttermilk being then drawn off and pumped into tanks, whence it is returned to the farmers.

The butter is then washed once or twice to remove any casein, "brined," and passed through a butter-worker, where it is kneaded or "worked," after which it is packed for the market.

Cheese-making.

In the production of hard cheeses, such as cheddar, the vat in which the cheese is made is usually provided with double sides and bottom, with inlets for steam and hot water at one end, and outlets at the other end for the hot water and the whey. The vat is filled with milk which is warmed up to a temperature of about 85° F. Rennet is added in the proportion of about one drachm to three gallons of the milk, which is then stirred for about ten minutes, and the vat covered up until coagulation occurs, the time required for this being about fifty minutes; when ready for cutting, the curd is sliced at equal distances with a curd knife, and about three minutes later the operation is repeated, the second cuts intersecting the first at right angles. The curd is thus divided into equal-sized cubes, allowing the whey to drain off. This constitutes the main polluting liquid in connection with cheese-making. In the case of soft cheeses, little whey is produced.

Cheese-making is generally carried on during those months of the year when the milk supply is plentiful and the price low.

Condensed Milk.

Condensed milk is produced by evaporating down the milk and adding sugar. The milk is weighed and stored in a large cool vat, from which it is passed through a pasteuriser, the temperature of the milk being thus raised to about 180° F. It then passes at once into a copper vat or mixer, where granulated sugar is added and incorporated with the milk. The process of mixing in the sugar lowers the temperature of the mixture to about 150° F. The mixture is next run into another storage vat, whence it is drawn off into the vacuum pan.

A gallon of milk evaporates down to about one-quarter of its original volume.

Several visits have been made to dairies where cream-separating, butter-making, cheese-making and the manufacture of condensed milk are carried on. On the occasion of each visit samples of the various waste liquids were taken for analysis, the figures of which are now appended.

Dairy No. 66.

Cream separation is the main branch of dairying carried on here, but milk powder is occasionally made and also butter.

The combined wastes are carried by open drains to a circular open concrete pond, where they mingle with the liquid manure from the farmyard and cowsheds, the combined liquid being drawn off by means of piping to the pasture land, where it is absorbed. About 10 acres are in use at any one time.

At the dates on which the samples were taken, the waste liquids were being given to pigs, together with the separated milk, none of them going on to the land; these samples were consequently very much stronger than the ordinary waste liquors, which do not contain separated milk.

DAIRY No. 66.

	No. 1.			No. 2.	No. 3.			
	Mixed wastes as fed to pigs (mainly separated milk).			Mixed wastes as fed to pigs.	Waste from Cheese-making.			
Drawn Analysed	February 21st, 1912. February 22nd, 1912.			April 23rd, 1912. April 26th, 1912.	October 10th, 1913. October 14th, 1913.			Oct. 15th, 1913.
Parts per 100,000	Original sample.	Paper filtered sample.	Neutralised with lime and filtered.	Paper filtered sample.	(*a*). Original sample.	(*b*) Paper filtered sample.	(*c*) Filtrate after the precipitation of the original sample with lime.	(*d*) Paper filtered sample heated to 100° C. for half-an-hour and again filtered.
Ammoniacal nitrogen	—	8·9	—	17·8	12·0	11·9	21·3	12·5
Albuminoid nitrogen	—	—	—	—	51·2	46·0	66·0	24·4
Total organic nitrogen	—	103·5	—	129·4	129·8	119·1	72·7	59·7
Total nitrogen (Kjeldahl)	124·0	112·4	—	147·2	141·8	131·0	94·3	72·2
Oxygen absorbed from N/8 permanganate at 80° F. at once	—	59·9	—	71·2	72·2	59·3	36·8	35·7
Oxygen absorbed from N/8 permanganate at at 80° F. in 4 hours	—	1464·0	—	2074·4	2146·3	2007·8	1471·9	2029·2
Dissolved oxygen taken up from tap water at 65° F. in 24 hours	—	—	27·7	—	—	—	—	—
Dissolved oxygen taken up at 65° F. in 48 hours	—	—	74·5	—	1230·0	745·0	660·0	692·0
Dissolved oxygen taken at 65° F. in 5 days	—	4850·0	181·0 + x	3940·0	5070·0 (6 days)	3740·0 (6 days)	2171·0 (6 days)	1754·0 + *x*
Dissolved oxygen taken up in 224 days	—	8392·0	—	—	—	—	—	—
Incubator test (by smell)	—	Foul rancid smell	—	—	—	—	—	—
Total solids	—	—	—	—	4605·6 {4048·8 V. 556·8 N.	—	—	—
Solids in suspension	(*a*) 170·0 {163·6 V. 6·4 N. (*b*) 214·8 {204·4 V. 10·4 N.	— —	— —	— —	Impossible to estimate satisfactorily.	—	—	—
Solids in solution	—	—	—	—	—	—	—	—
Acidity from organic and volatile acids (as H_2SO_4)	—	451·0	—	197·8	417·3 approx.	295·3	—	314·6
Acidity after boiling (,, ,,)	—	—	—	—	305·0 approx.	292·1	—	—
	Yellowish turbid liquid, with much white coagulated suspended matter. Strong sour cheese smell. Acid re-			Same in appearance and smell as sample of February 21st, 1912.	Thick and milky. Very little real suspended matter. Sour milk and cheese smell.	Yellowish and cloudy.	Slightly cloudy, but not so yellow as (*a*) or (*b*).	Yellow, but almost clear.

It requires but a glance at the foregoing figures to recognise the excessively polluting nature of this mixed liquid waste. The nitrogen present (nearly all of it organic nitrogen) amounted to about 120 to 190 parts per 100,000, while the dissolved oxygen taken up in 5 or 6 days by the paper filtered samples was between 4,000 and 5,000 parts. Sample No. 1, after paper filtration, took up 4,850 parts of oxygen in 5 days, while 8,392 parts (=8·4 per cent by weight of oxygen) were required for its complete oxidation. Most of the organic matter present was thus capable of fairly rapid oxidation.

The acidity (from organic acids) varied from about 200 to 450; this acidity of course increases as the sample is kept. It might be worth while to consider whether those portions of the waste which contain the bulk of the milk sugar or lactic acid might not profitably be collected, apart from the other portions, and treated for the production of this acid, which has various technical applications.

The filtration of No. 3 sample through paper did not greatly reduce the organic impurity, but after it had been neutralised by lime and the insoluble precipitate filtered off, the organic matter in it was reduced by nearly one-half.

A few laboratory experiments were made with the object of testing how far this kind of waste was amenable to biological purification, and these may be briefly referred to here. They are, however, only to be taken as indications, much more prolonged data being required for an authoritative statement.

(1) When 1 volume in each instance of this waste was mixed with 29,19, and 9 volumes of a weak septic tank liquor from sewage plus a known excess of tap water, the dissolved oxygen taken up from the water by the mixture was nearly the calculated amount, thus:

	Parts per 100,000.
Dissolved oxygen taken up from tap water by Dairy Waste alone, in 4 days	3,310
Dissolved oxygen taken up from tap water by Septic Tank Liquor, in 4 days	11·2

	Mixture.	Calculated Dissolved Oxygen Absorption.	Actual Dissolved Oxygen Absorption.
(a)	1 vol. Dairy Waste 29 vols. Septic Tank Liquor 399 vols Tap Water	121·4	139·6
(b)	1 vol. Dairy Waste 19 vols. Septic Tank Liquor 599 vols. Tap Water	176·1	181·8
(c)	1 vol. Dairy Waste 9 vols. Septic Tank Liquor 999 vols. Tap Water	341·0	290·0

It may thus be taken that when such waste is mixed with septic tank liquor from sewage in a proportion up to 1 in 20, or, probably, 1 in 10, the biological oxidation of the sewage liquor will not be interfered with, so far, at least, as the actual power of taking up oxygen is concerned; in other words, the whole will be amenable to biological purification.

(2) When 1 volume of the waste (after paper filtration) was mixed with 9 volumes of septic tank liquor and the whole allowed to stand at air temperature for 19 hours, the mixed liquid (siphoned off from the solids) showed good purification when passed through a laboratory biological filter. To give only two results from each analysis:—

	"Oxygen absorbed" from N/8 permanganate in 4 hours at 80° F.	Incubator test (by smell).
Mixture before biological filtration	201·0	—
After filtration at a rate of 12·6 gallons per cube yard per 24 hours	1·69	Passed
After filtration at a rate of 22·2 gallons per cube yard per 24 hours	9·42	Failed

In looking at this result, it has to be borne in mind that the liquid thus treated on the experimental filter was something like five times as strong, organically, as an average sewage.

(3) Some laboratory experiments were also made on the biological filtration of the (paper-filtered) waste after diluting it with 9 volumes of tap-water (*i.e.*, without any admixture of sewage liquor). As will be seen from the table which follows, the organic strength of this mixture was more or less the same as that of the preceding one, when the diluent

was septic tank liquor from sewage. Here, again, fair or good purification was effected; the data, however, are not sufficient to allow of a comparison of the actual purification per cube yard of filtering material in the two cases.

	Diluted Dairy waste before passing on to filter.	Final effluent from filter.	Number of filtrations.	Average rate of filtration (gallons per cube yard per 24 hours).
Experiment.	"Oxygen absorbed" from N/8 permanganate in 4 hours at 80° F.			
(a)	160	1·7	3	Less than 5
(b)	207	12·0	4	„ 4·7
(c)*	207	3·4	3	„ 13·5

* Between experiments (b) and (c) the filter has rested for 48 hours.
All three effluents (a, b and c) withstood the incubator test.

Dairy No. 67.

At this dairy, cream-separating, cheese-making and the manufacture of condensed milk are carried on. No cheese was being made at the time of the visit.

The analytical figures given below refer to a sample containing rinsings from milk cans and drainage from floors.

Parts per 100,000.	Sample of Waste Liquor from rinsing of Milk Cans and drainage from Floors.
Drawn	February 27th, 1912.
Analysed	February 28th, 1912.
Ammoniacal Nitrogen	·015
Albuminoid Nitrogen	·198
Nitrous Nitrogen	·12
Nitric Nitrogen	·39
Oxygen absorbed from N/8 permanganate at 80° F. at once	·43
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	4·28
Dissolved oxygen taken up from tap water at 65° F. in 24 hours	4·30
Dissolved oxygen taken up at 65° F. in 48 hours	6·70
Dissolved oxygen taken up at 65° F. in 5 days.	11·65
Incubator test (by smell)	Putrid; H_2S.
Chlorine	2·90
Solids in suspension	5·4 { 4·0 V. 1·4 N.
Total hardness (as $CaCO_3$)	61·3
Hardness after boiling (as $CaCO_3$)	49·3
Acidity from organic acids (as H_2SO_4)	3·6
Remarks	Opalescent liquor with a moderate amount of fine brown solids; practically no smell. Neutral to litmus.

The foregoing sample was very dilute, being only about one-fourth as polluting as an average sewage. Filtered through a small laboratory biological filter at the rate of 32 gallons per cube yard per day, it yielded an effluent which gave a 4 hours "oxygen absorbed" figure of 1·34, and which took up only 0·13 part dissolved oxygen from tap water in 5 days. It is to be inferred that such a dilute waste as this might, in practice, be filtered at a considerably higher rate per cube yard; but experiments on a large scale are required.

The following samples were taken at Dairy No. 68, when cheese-making was in progress.

The crude waste liquor sample consisted of a mixture of all the waste liquids, before it passed through the settling tanks and the percolating filter which are provided for its treatment. A sample of the filter effluent was also taken. The distribution of the tank liquor on the filters was very imperfect.

There are three tanks, each 8 feet by 7 feet by 12 feet deep, with a total capacity of 12,600 gallons. The filter measures 25 feet by 16 feet by 5 feet deep, with a liquid capacity of about 4,000 gallons. The material consists of medium-sized broken saggers. The total flow of waste liquor, resulting from a full day's work in summer, amounts to about 10,000 gallons per 24 hours.

The tanks are seldom cleaned out.

The samples gave on analysis the following figures :

DAIRY No. 68.

Parts per 100,000.	No. 1. Mixed wastes from cheese-making.	No. 2. Filter effluent.
Drawn	July 29th, 1913. 3.45 p.m.	July 29th, 1913.
Analysed	July 31st, 1913.	July 31st, 1913.
Ammoniacal Nitrogen	·34	·63
Albuminoid Nitrogen	4·18	1·93
Total organic Nitrogen	10·36	3·71
Total Nitrogen (Kjeldahl)	10·70	4·34
Oxygen absorbed from N/8 permanganate at 80° F. at once	6·84	2·64
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	68·58	28·73
Dissolved oxygen taken up from tap water at 65° F. in 48 hours	161·0	71·6
Dissolved oxygen taken up at 65° F. in 5 days	281·0	113·6
Total solids	549·2 { 312·8 V. 236·4 N.	264·4 { 90·8 V. 173·6 N.
Solids in suspension	53·5 { 51·5 V. 2·0 N.	22·4 { 20·8 V. 1·6 N.
Acidity from organic acids (as H_2SO_4)	54·0	29·7
	Milky white liquor, with a considerable amount of curdy white suspended matter. Sour smell. Acid reaction.	Less turbid than No. 1, with a moderate amount of flocculent white suspended solid. Flies and worms (dead). Putrid smell. Considerable H_2S.

Of these two samples, the mixed waste from cheese-making was very polluting, probably about six times as much so as an average domestic sewage; it was relatively more carbonaceous than the latter. From the figures of analysis of the effluent it will be seen that the treatment as carried out was very imperfect, the effluent being still very impure—probably about twice as polluting as an average sewage. The purification plant—both tanks and filter—at this dairy is much too small for the work it has to do.

No biological filtration experiments were made with this waste.

Dairy No. 68a.

The following figures of analysis refer to a fairly average sample of composite waste from an Irish Co-operative Creamery, No. 68a. At the time when it was drawn the total volume of waste amounted to only 1,150 gallons per day, from 250 gallons of milk and 67 gallons of cream churned. In summer this creamery separates 3,000 gallons of milk daily and churns about 840 gallons of cream.

Parts per 100,000.	
Drawn	Wednesday, January 21st, 1914.
Analysed	January 26th, 1914.
Ammoniacal Nitrogen	5·24
Albuminoid Nitrogen	4·52
Total organic Nitrogen	8·59
Total Nitrogen (Kjeldahl)	13·83
"Oxygen absorbed" from N/8 permanganate at 80° F. at once	7·15
"Oxygen absorbed" from N/8 permanganate at 80° F. in 4 hours	54·7
Dissolved oxygen taken up from tap-water at 65° F. in 48 hours	123·0
Dissolved oxygen taken up from tap-water at 65° F. in 5 days	223·5
Total solids	288·8 { 192·8 V. 96·0 N.
Solids in suspension	96·2 { 79·4 V. 16·8 N.
Acidity from organic acids (as H_2SO_4), (phenol-phthaleïn)	13·5
Alkalinity (as H_2SO_4), (methyl orange)	35·5
Fatty matter extracted by ether, after acidification	84·2
Fatty matter extracted by ether, without acidifying	79·0

A few laboratory experiments were made in order to gain an approximate idea of the effect of settlement and precipitation on this class of waste. These showed that settlement for three hours reduced the organic impurity (as judged by the "oxygen absorbed" in 4 hours) by about 25 per cent.; while precipitation with 3 parts per 100,000, of alumina (added as sulphate) and 10 parts of lime, and subsequent settlement for three hours, reduced it by about 50 per cent.

Summary as regards Dairy Waste.

The waste liquids produced at a dairy vary greatly, according to the particular branch of the business carried on for the time being.

When cheese-making is in progress, the mixed liquids are excessively polluting in character, being, at a moderate estimate, from 5 to 10 times the strength of an average domestic sewage.

At those dairies where the waste consists merely of the washings of vessels and floors, and butter-making is not in progress, it is weaker, but still distinctly polluting, and liable to cause much nuisance if discharged crude into a small stream. Still, whether strong or weak, we infer, from the few laboratory experiments which we have been able to make, that it is amenable to purification by biological methods. Further, provided it is sufficiently clarified, and not allowed to become unduly acid, we see no reason to doubt that its purification—whether on biological filters or upon land—would be analogous to, though probably slower than, that of ordinary domestic sewage, allowing for the difference in strength.

We understand that an example of satisfactory land treatment is to be found in Ireland, where a strong creamery sewage is treated by straining through a shallow bed of peat, to remove solids prior to filtration through land of only moderate quality. The rate of filtration is about 2,300 gallons per acre per 24 hours.

Where suitable land is not available, good clarification, followed by deep percolating filters, would appear to offer an alternative means of purification, but we can point to no example of this method of treatment upon a practical scale, and it is necessary, therefore, in view of the rapid development of the dairying industry, that we should draw attention to the need for systematic investigation, directed not only to biological purification, but also to the utilisation of what is valuable in the waste products.

In the meantime we should infer from what little work we have done on the subject, conjoined with our general experience of wastes of organic character, that dairy waste could be purified practically so as to produce an effluent containing not more than 4 parts suspended solids per 100,000, and taking up not more than 4 parts of dissolved oxygen in 5 days.

In the case of dairies situated in towns, it is desirable that the waste liquors should be admitted to the sewers for treatment at the sewage works.

Since it has been shewn that certain mixtures of dairy waste and sewage are amenable to biological purification, it may be anticipated that the purification of the sewage will not be markedly affected unless the dairy waste happens to be in preponderating amount.

The greasy solids which dairy waste contains may, however, materially affect the clarification process adopted at the sewage works, and it is therefore advisable to see that they are removed as far as practicable before the liquor is discharged to the sewers.

Margarine Waste.

88. There are only some three or four manufactories of margarine in this country, all of them situated in urban districts and all draining to the sewers. For this reason we have not made much inquiry into the subject, but a visit was paid to one large factory (No. 69), and two samples were taken.

Waste liquor from the manufacture of margarine consists of washings from tubs, apparatus and floors, and may be described as dirty, greasy water.

The waste liquids at these works are subjected to settlement in tanks, and the greasy matter rising to the surface of the first tank is skimmed off at intervals and sold. The tank liquor is discharged into the local sewers.

MARGARINE FACTORY No. 69.

	Crude mixed waste as entering tank.		Tank effluent.	
Drawn - - - - - - -	June 6th, 1912, 4.30 p.m.		June 6th, 1912, 4.30 p.m.	
Analysed - - - - - -	June 7th, 1912.		June 7th, 1912.	
Parts per 100,000.	Original sample.	Paper filtered sample.	Original. sample.	Paper filtered. sample
Ammoniacal Nitrogen - - - -	1·32	1·32	1·64	1·56
Albuminoid Nitrogen - - - -	3·18	1·94	1·75	·89
Total organic Nitrogen - - - -	8·18	5·00	3·40	1·92
Nitrous Nitrogen - - - - -	·50	—	—	—
Nitric Nitrogen - - - - -	·05	—	—	—
Total Nitrogen (Kjeldahl) - - -	10·05	6·87	5·04	3·48
Oxygen absorbed from N/8 permanganate at 80° F. at once - - - -	5·67	2·69	2·75	1·59
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours - - - -	89·10	70·70	35·04	28·08
Dissolved oxygen taken up at 65° F. in 48 hours - - - - - - -	(*a*) †134·7 (*b*) † 89·1	(*a*) 75·2† (*b*) 71·2†	(*a*) 78·4 —	54·5 —
Dissolved oxygen taken up at 65° F. in 4 days - - - - - - -	(*b*) 129·0	(*b*) 84·0	114·0	50·6
Incubator test (by smell) - - - -	Quite sweet; oily smell.	Sweet.	—	—
Chlorine - - - - - - -	450.0	—	290·0	—
Total solids - - - - - - -	1132·8 { 299·2 V. 833·6 N.	— —	664·0 { 103·6 V. 560·4 N.	— —
Solids in suspension - - - -	123·6 { 106·6 V. 17·0 N.	— —	39·0 { 33·4 V. 5·6 N.	—
Solids in solution (by difference) - -	1009·2 { 192·6 V. 816·6 N.	— —	625·0 { 70·2 V. 554·8 N.	— —
Total hardness (as $CaCO_3$) - - -	82·9	—	75·0	—
Permanent Hardness (as $CaCO_3$) - -	78·9	—	72·1	—
Acidity from organic acids (as H_2SO_4) -	27·1	—	30·8	—
Acidity on incubated sample - - -	58·4	39·1	—	—
Fat, *i.e.*, ether extract* - - - -	349·5 { 347·3 V. 2·2 N.	1·3 { 0·5 V. 0·8 N.	37·9 { 34·8 V. 3·1 N.	2·2 { 0·6 V. 1·6 N.
	Turbid and milky looking. Much whitish flocculent suspended matter and much oily matter floating on the surface. No smell.		Very turbid milky liquor, with a small quantity of suspended matter—mostly fine. Strong sulphuretted hydrogen odour.	

* Most probably after acidifying. † Done on different bottles of the sample.

The chief characteristics of this waste liquor were the comparatively large amounts of fat (about 350 parts per 100,000) and of common salt (about 700 parts) present, the acidity being but small; it took up 129 parts of dissolved oxygen in 4 days. After the fat and the insoluble organic matter had been separated by filtration through paper, the liquid still took up 70 to 75 parts of dissolved oxygen in 2 days and 84 parts in 4 days.

The effluent from the settling tank contained 35 parts of fat, and took up 114 parts of dissolved oxygen in 4 days.

The very polluting character of such liquids is thus apparent.

The question of the purification of this waste when unmixed with sewage does not arise at the present time. We may point out, however, that the grease which it contains may be objectionable in sewers, and have an injurious clogging effect in biological filters and on land. In our opinion the grease ought always to be removed.

Waste Liquor from Shale Oil Distillation.

89. A fairly detailed account of the Shale distilling industry is to be found in Thorpe's *Dictionary of Applied Chemistry*, Second Edition, Vol. IV., p. 50 (1913).

So far as the United Kingdom is concerned the industry is a Scottish one, and in Scotland, excepting for one works in Lanarkshire, it is confined to rural areas in the counties of Linlithgow and Midlothian, and almost entirely to the basin of the river Almond in Midlothian. It was begun in the middle of last century by the late James Young of Kelly. The number of shale distilling works in these two counties now amounts to twelve. The minerals wrought are, with one or two exceptions, certain seams of shale lying between the coal formation and the old red sandstone.

The manufacturing processes of distillation, separation of the various grades of oil from one another, and purification, are substantially the same at all the works in the district. Of these we visited three, and one (No. 70) was subsequently re-visited by one of our Officers for the purpose of obtaining samples of the waste liquors and the purified effluent.

A brief description may be given of the manufacturing process, as generally carried out, the ultimate products obtained being naphtha, burning oil, medium or light mineral oil, lubricating oil, solid paraffin and sulphate of ammonia.

The mined shale is delivered in small lumps into continuous feed retorts, surrounded by a jacket of burning gas. The oil gas evolved is condensed practically into two rough grades, the gases which remain uncondensed being then washed with water, to which they give up their ammonia. The residual washed gas is passed back to the retorts, to be used for heating.

The two grades of oil are refined by repeated distillations and by repeated alternate treatments with strong sulphuric acid and strong solution of caustic soda, this being usually carried out in large malleable iron boilers. The acid treatment removes the greater part of the tarry matter of the crude oil, consisting of pyridine bases, pyrrol, etc., while the soda treatment absorbs the cresylic and phenylic bodies; "acid tar" and "soda tar" are thus obtained.

Generally, the acid tar is washed with hot water, and the mixture stirred up with air and settled. This separates the acid from the greater part of the tarry bases precipitated by it, and the resultant weak acid liquor is used in the manufacture of sulphate of ammonia.

There is also at some works a process for recovering the soda from the soda tar. Carbon dioxide from a coke fire is forced through the tar as it comes from the washers, carbonate of soda being formed and creosote oil liberated; this latter is used for creosoting sleepers, etc. The carbonate of soda is causticised and used again for crude oil purification.

The acid and soda tars are then mixed together and prepared for burning as fuel under the stills.

At works No. 70, the acid and soda liquors from the treatment of the crude oils are mixed together in such proportions as to leave a slightly acid liquor, the result being that a tar separates out. This tar is used as fuel. The residual liquor (sodium sulphate liquor) is then discharged.

The "gas liquor," *i.e.*, the water from the scrubbers in which the ammonia from the shale distillation has been condensed, is distilled for the recovery of ammonia, a little lime being added towards the end of the operation. The ammonia is condensed in the usual way in oil of vitriol to sulphate of ammonia. The spent liquor is a waste.

There are thus two waste liquors from a shale oil works, viz., (1) the sodium sulphate liquor, and (2) the spent gas liquor.

At works No. 70 about 2,100 tons of shale are at present (1914) dealt with per day and the approximate daily volumes of the waste liquors are:

	gallons.
Sodium sulphate liquor - - - - - -	8,000
Spent gas liquor - - - - - - -	184,000

The works run continuously, day and night, Sundays and Bank Holidays included, so that the flow of spent gas liquor is practically continuous. The flow of sodium sulphate liquor is, however, intermittent.

The two waste liquors are delivered into a series of five settling tanks, having a total capacity of about 82,000 gallons, and, after settlement, the mixed liquor is pumped on to immense heaps or "bings" of the spent shale from the retorts—heaps of loosely compacted filtering material, which get larger and larger as the works grow older, and which may almost be called small hills. The liquor is poured on to different parts of the top of a bing, the point of discharge being altered from time to time.

At the date of our visit, two of the bings were being utilised in this way—an old one, probably still hot in the interior, and another one in present use as a tip for the spent shale. The latter bing was obviously hot, the effluent from it having a temperature of 70°F., although the weather was frosty. This warm effluent, which was a little turbid from suspended matter, drained under the old heap which was receiving the second portion of the waste liquor, the two effluents issuing as one in a ditch near the canal. There was, no doubt, also some surface water intermixed. The combined effluent was clear and bright, and with only a very faint dry smoky smell. The ditch was coated for 20 or 30 yards with a bluish-white deposit, which was found, on subsequent examination, to consist of a basic salt of alumina, produced by the action of the sulphate of the waste liquor upon the alumina present in the spent shale.

The following are the analyses of the average samples which we took in January, 1910:

SHALE DISTILLING WORKS No. 70.

Samples Drawn January 23rd, 1910. Parts per 100,000.	No. 178. Sodium sulphate waste liquor. Average of 4 samples, taken in equal quantities each hour, from 7 to 10 a.m. inclusive. This is a mixture derived from the acid and alkaline treatment of the crude oil.	No. 179. Spent gas liquor (crude). Average of 12 samples, taken every 2 hours from 7 a.m. January 23rd, 1910, to 6. a.m. January 24th.	No. 180. Mixed and settled liquor, as pumped on to waste heap. Average of 24 hours, in equal quantities every 2 hours.	No. 181. Final effluent from waste heap. Average of 24 hours, in equal quantities every 2 hours. Opalescent, with bluish-white suspended matter, which ultimately deposited.
Analysis begun	February 11th, 1910.	April 18th, 1910.	February 11th, 1910.	February 7th, 1910.
Ammoniacal nitrogen	2·34	5·72	11·10	0·81
Albuminoid nitrogen	0·78	1·36	1·76	0·08
Total organic nitrogen	11·40	3·46	3·26	0·54 (?)
Nitrous nitrogen	Not estimated.	—	—	0·0
Nitric nitrogen	2·42	—	0·0	2·94
Total nitrogen (Kjeldahl)	16·16	9·18	14·26	4·29
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.) at once	37·03	68·27	71·0	0·33
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.) in 4 hours	123·3	93·73	88·2	1·40
Dissolved oxygen taken up from tap water at 18° C. (65° F.) in 48 hours	—	—	—	0·36
Dissolved oxygen taken up from tap water at 18° C. (65° F.) in 5 days	—	—	—	1·35
Oxygen in solution	—	—	—	0.47
Incubator test (by smell)	—	—	—	Passed (slight sooty smell).
Total solids	—	262·4 { 64·4 V. 198·0 N.	188·0 { 44·6 V. 143·4 N.	154·9 { 19·4 V. 135·5 N.
Solids in suspension	Not estimated.	76·2 { 13·0 V. 63·2 N.	6·3 { 4·3 V. 2·0 N.	4·5 { 1·6 V. 2·9 N.
Solids in solution	4387·2 { 258·3 V. 4128·9 N.		—	—
Hardness by soap test (expressed as $CaCO_3$)	—	—	—	115·7
Hardness after boiling (expressed as $CaCO_3$)	—	—	—	116·8
Acidity (expressed as H_2SO_4), using methyl-orange	113·3	—	—	—
Alkalinity (expressed as H_2SO_4), using methyl-orange	—	—	18·3	5·3
Total sulphur	—	60·8	—	—
Sulphur present as Thiocyanate	—	8·1(=14·7 CNS)	—	—
Sulphur present as Sulphide	—	0·0	—	—
Sulphur present as Sulphate	—	?	—	—
Sulphur present as Thiosulphate	—	?	—	—
Zinc	—	—	—	0·96
Notes	Yellowish-green but clear, with some separated tar, which was left out of the analysis. A little flocculent suspended	Yellowish liquor, when settled, with much red-brown solids. Tarry smell. Frothy. The filtrate from the suspended solids	Reddish-brown and turbid, with much fine red suspended matter. Strong pungent tarry smell. Alka-	Bright and clear, with some white flocculent suspended matter. Pungent sooty odour.

The results of the foregoing analyses may be shortly summarised as follows:

Sample No. 178. *Sodium sulphate waste liquor.*—This was a slightly acid solution of sodium sulphate, containing very considerable quantities of tarry and nitrogenous matters.

Sample No. 179. *Spent gas liquor.*—This contained considerable amounts of tarry and sulphur compounds (though possibly the latter consisted mainly of sulphate). It also contained a good deal of mineral suspended solid.

Sample No. 180. *Mixed and settled liquor as pumped on to waste heap.*—This was a reddish-brown and turbid liquid, with about 6 parts of finely-divided suspended matter per 100,000. It contained a good deal of nitrogen, mainly in the form of ammonia, and had a strong, pungent, tarry smell.

Sample No. 181. *Effluent from waste heap.*—This effluent, which had percolated through a bing some 200 feet high, was of excellent quality. It was about half aerated when analysed (a fortnight after being drawn), was well nitrated, contained very little oxidizable matter of any kind, and took up only 1·35 parts of dissolved oxygen from water in 5 days. The good nitration of the effluent, contrasted with the unoxidized nitrogen in the mixed waste liquor, points to biological oxidation in the cooler parts of the heap.

It will be seen, however, that the effluent was very hard (with permanent hardness), no doubt from the action of the sulphate of soda on the magnesia and lime of the spent shale. The only poisonous metallic ingredient that it contained was a small quantity of zinc (0·96 part per 100,000).

The flocculent suspended solids (4·5 parts) were mainly mineral.

In the earlier years of this industry the river Almond was badly polluted by the discharges from the works then in existence, as is shewn by the following extracts from the Fourth Report of the Rivers Pollution Commission (1870):

"It (the Almond) has long been to some extent polluted at certain seasons of the year with the waste from the process of flax-steeping, and also more constantly, though not to any great degree, with the drainage water of coal pits. Within the last few years, however, it has become most offensively fouled by the waste waters from paraffin oil works, which have spoiled it for almost every purpose to which it has hitherto been applied. When the water is low, and the nuisance therefore is greatest, it is no longer drinkable by cattle—it is no longer useful for any domestic purpose—it is no longer serviceable even for sheep washing—it is no longer the good trouting stream which it used to be—it is even said to have infected the well waters in its neighbourhood." (Vol. II., Part III., Q. 2123.)

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"The inhabitants of Linlithgow complained loudly of the discomfort and damage which they suffer from this class of pollution. We were informed that the oil floating on the streams could be ignited, burning with a large flame. . . ."

* * * * * * * * * *

"These foregoing analyses shew that very considerable quantities of oil escape in the effluent water from these works, whilst the proportions of dissolved impurities, represented in the table by organic carbon and organic nitrogen, are sometimes very high in the discharges, fully justifying the complaints made against the nuisance. As already mentioned, the polluting power of paraffin oil is so intense and persistent that very much smaller proportions of this form of organic matter than those suggested by us as standards for purity, create, when admitted into running water, a formidable and incurable nuisance. If this kind of pollution is to be effectively dealt with, it will be necessary to prohibit, from oil or tar or petroleum distilleries, all discharges containing any appreciable amount of oil in suspension or exhibiting a perceptible film of it floating on the surface. . . ."

* * * * * * * * * *

Under the heading "Remedies" we find the passage:

"The foulness which these refuse liquids (from shale works) communicate to water is exceedingly persistent and is irremovable by any practical means. The liquids themselves also contain fœtid organic matter, which oxidizes with extreme difficulty; they cannot therefore be cleansed by intermittent filtration, neither are they much ameliorated by any other known purifying process. Total exclusion, therefore, from running water is the only remedy for this form of river pollution. Fortunately the volume of the polluting liquids is not large, and a portion of them admits of conversion into marketable produce, in some cases at a profit, in others at an insignificant loss."

(At this time the recovery of ammonia from the ammonia liquor had not become universal.)

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"An absolute prohibition of all drainage into streams from paraffin and petroleum works would, in our opinion, inflict no serious hardship upon these branches of manufacture. As the drainage from paraffin oil works and petroleum works, if mixed with sewage, interferes with the cleansing of the latter by irrigation or intermittent filtration, it ought not to be allowed admission into the sewerage system of towns."

Since the Rivers Pollution Commission published their report on the subject the problem of purifying the waste liquors from shale distilling works has become, if not simple, at least much simpler than it was at that time. The economic advantage in recovering all the ammonia from the aqueous portion of the distillate has contributed to this; but still more the fact that with every day's output the size of the bing of spent shale has increased, so that these now represent an enormous area available for filtration purposes. Of the 13 shale oil works in Scotland, all excepting two (which pump their waste liquids to the Firth of Forth) utilize the bings for filtration.

In 1904–5 an investigation was made by Professor C. Hunter Stewart, at the instance of the Court of Session, Edinburgh, upon the nature and the purification of the waste liquors at the two works of Pumpherston and Oakbank in Midlothian. In summarising his results, he expressed the opinion that, while it would be a distinct advantage if a method could be devised for the removal of the large amount of sulphate of soda and sulphate of lime from the waste liquors, the only way of doing this, *with the present method of working*, would be by evaporating the "soda tar water," the cost of which would be prohibitive.

He recommended, however, certain modifications in the preliminary treatment of the waste liquors, so as to ensure that a series of separators should effect the best possible separation of oil and tar from the waste liquor before it was pumped on to a bing. He found that

> "the removal of oily matter, tar, pyridine bases, etc., from the impure effluent (*i.e.*, waste liquor) in the course of its filtration through the spent shale bing is partly due to absorption of these substances and partly to evaporation. I made some experiments on this point and found that these substances were better absorbed by hot than by cold spent shale. This is probably due to the higher temperature of the fluid and to the greater water absorption capacity of hot dry shale, as compared with that over which the effluent has been passing for some time. I am of opinion that the eminently satisfactory results obtained at these (Pumpherston) works are, in part at least, due to the effluent being discharged on to the hot portion of the bing."

He found the general results of the purification at Oakbank very satisfactory also, but suggested some changes in the method of treatment.

We understand from Dr. Alexander Robb, Medical Officer of Health for Midlothian, that all the bings in Mid- and West Lothian are large enough for good purification of the waste liquors, that the effluents are generally satisfactory in appearance, and that the state of the river Almond is fair, though it and its tributaries are actually affected by some escape from oil works, such as surface drainage during heavy downpours of rain. Such surface drainage pollution would naturally be most apparent when heavy rain occurred after a period of dry weather, and not when the streams were in flood. Dr. Robb considers that, generally speaking, care is taken by those in charge of the shale oil works to prevent streams being polluted by waste liquors.

Dr. J. T. Wilson, Medical Officer of Health for the County of Lanark, is of the same opinion with regard to the shale oil works in his county.

Summary as regards the waste from shale oil distilling.

It is, we think, evident that the purification of the waste liquors from shale distilling works presents now no special difficulty, provided that care and attention be given to it. In connection with this it is obviously important to effect, by means of separators, as complete a separation as possible of oily and tarry matters from the waste liquors before attempting their filtration; and it is also important that, as far as possible, all surface drainage from a works and the surrounding ground should gravitate to a pond, where oily matter would separate on the surface, before the watery portion was pumped on to the bing.

In view, therefore, of the highly polluting character of the unpurified waste liquors from shale oil works, and of the fact that each of the existing works has now a large bing or heap of spent shale available for filtration purposes (a heap which is daily increasing in size), we consider that such liquors ought always to undergo a thorough purification. It is, we think, reasonable to suggest that this effluent should be of such purity as not to contain more than 4 parts of suspended solids per 100,000, and not to take up more than 4 parts of dissolved oxygen from water in 5 days.

It may, in addition, become a question for the local Rivers Authorities to formulate specific requirements, which will ensure that effluents from shale oil works are practically free from all visible oily and tarry matter in suspension.

As already indicated, such effluents from spent shale heaps are of necessity very hard.

Nearly all the shale oil works are in rural districts, so that the question of admission of crude liquor to sewers hardly arises.

It has to be remembered that the volume of waste liquor produced at a shale works is large, and bears no relation to the surrounding population. It is thus in a different category from the waste liquor from a local gas works.

Spent Gas Liquor.

90. Spent gas liquor is, of all trade wastes, probably the most difficult to deal with. It is produced in large volumes and in all parts of the country, but, fortunately, improved procedures in the distillation of coal are tending to lessen the quantity materially, per ton of coal distilled for coke production, as time goes on.*

By the term "spent gas liquor" we mean the brown coloured aqueous solution, smelling of tar, which is produced in the recovery of the ammonia from:

(1) The manufacture of coal gas for lighting purposes.
(2) The coking of coal.
(3) The manufacture of producer gas, for heating.
(4) The waste gases of blast furnaces.
(5) The distillation of shale for oil, discussed in the preceding pages.

We confine our remarks here to the liquor from coal.

When coal is distilled or used for any one of the purposes just enumerated, a considerable quantity of water vapour—something like 18 per cent. by weight of the coal—among other things, is given off. This comes partly from the moisture in the coal itself, and is partly produced by the destructive distillation. Another volatile product is ammonia, a certain proportion of the complex nitrogen compounds of the coal being broken down by the heat into this simpler substance. Being a most valuable by-product, this ammonia has to be prevented from escaping into the atmosphere. In the most recent types of coal-distilling apparatus for coke production this is effected without the aid of additional water, but in the majority of cases it is still done by passing the vapours from the oven (after first condensing as much of the tar as possible) through a water scrubber. The brown aqueous solution thus obtained is known as "ammonia liquor." This is in its turn distilled, some lime being added in the later stages of the distillation. The ammonia evolved is condensed in sulphuric acid to sulphate of ammonia, the residue in the still being "spent gas liquor" or "spent ammonia liquor." At some gas works the ammonia liquor is distilled on the spot, but usually it is sold to chemical manufacturers, to be treated by them. The waste liquors amount to something like 100 to 120 gallons per ton of coal distilled—say, 50 to 55 per cent. by weight.

Since all the condensed tarry matter from the distillation of coal is utilised in one way or another, gas liquor is the only liquid waste from this process. A very foul liquor, known as "devil water," is obtained by the condensation of the vapours escaping from the sulphuric acid in the saturator, after it has absorbed the ammonia distilled from the gas liquor. This is generally, we understand, returned to the storage tank for gas liquor, and it ought certainly to be always returned, and never run off.

As already mentioned, the most modern types of plant for the coking of coal can be worked so as to produce only very small volumes of waste liquors; in ordinary practice such plants yield much smaller amounts of waste liquors than those of the older type. We have heard some evidence in regard to these (7th Report, Vol. III., Part II.) Although there are comparatively few of such plants in use, we may expect them to increase, with a corresponding diminution in the amount of spent gas liquor. These new procedures may be briefly termed:

The complete direct absorption process for recovery of the ammonia from coal distillation; and
The partial direct absorption process.

In the complete direct absorption process the gases from the ovens are never allowed to cool below about 120° C., consequently there is no condensation of aqueous vapour. The tarry compounds in the vapour are removed by scrubbing with hot tar oils, prior to the vapour passing through sulphuric acid in the saturator, for absorption of the ammonia. From the saturator the residual gases pass on direct to the coke oven flues, to be burnt. The Otto-Hilgenstock process belongs to this category. When the plant is working at its best, only 4½ gallons of waste liquor per ton of coal distilled are said to be produced;†

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* An excellent and comparatively detailed account of the subject, including a number of analyses, is given in Messrs. Wilson and Calvert's "Trade Waste Waters," pp. 24 to 50 (1912).

† Even this comparatively small volume is not, however, negligible; thus, if we imagine a medium-sized battery of coke ovens, 50 in number, each carbonising 7 tons of slack per 30 hours, the waste liquor produced would amount to 1,230 gallons per 24 hours.

Parts per 100,000.	No. 157. Colliery No. 71. *Spent gas liquor*: partially settled. Average of 5 samples taken in equal quantities every hour.	No. 189. Iron Works No. 72. *Spent gas liquor.* Average of 24 hours, in equal quantities every hour.	No. 190. Steel Works No. 73. *Condensed vapour from Producer Gas.* Average of 24 hours, in equal quantities every hour.	No. 191. Steel Works No. 73. *Exhaust Water from Ammonia liquor evaporation.* Average of 24 hours, in equal quantities every hour.	No. 192. Steel Works No. 73. *General effluent.* Average of 24 hours, in equal quantities every hour.	No. 06. Gas Works No. 74. *Spent liquor from Sulphate of ammonia recovery plant.* Chance sample.	No. A. Gas Works No. 75. *Spent Gas Liquor.* Chance sample.	No. B. Gas Works No. 75. *Spent Gas liquor.* Average sample, taken every half hour on April 23rd, 1914, from 3 p.m. to 7 p.m., and on April 24th, from 7 a.m. to 11 a.m.
Drawn - - -	Dec. 16th, 1909, 7.30–11.30 a.m.	Jan. 27th, 1910, 9 a.m., to Jan. 28th, 1910, 8 a.m.	Jan. 31st, 1910, 12 noon, to Feb. 1st, 1910, 11 a.m.	Jan. 31st, 1910, 12 noon, to Feb. 1st, 1910, 11 a.m.	Jan. 31st, 1910, 12 noon, to Feb. 1st, 1910, 11 a.m.	May 19th, 1910.	March 23rd, 1914.	April 23rd and 24th, 1914.
Analysis begun - -	Jan. 24th, 1910.	Feb. 25th, 1910. ‖	June 13th, 1910.	April 22nd, 1910.	April 25th, 1910.	May 23rd, 1910.	April 6th, 1914.	April 30th, 1914.
Ammoniacal nitrogen - -	2·86	0·24	1·36	0·14	0·38	85·2	24·9	37·4
Albuminoid nitrogen - - -	0·76	1·28	0·97	0·16	0·44	21·6	19·0	33·5
Total organic nitrogen - -	3·46	2·92	3·57	—	—	80·0	64·1	95·6
Nitrous nitrogen - - -	—	—	—	—	—	—	—	—
Nitric nitrogen - - - -	0·07 (?)	0·0	—	—	—	—	—	—
Total nitrogen (Kjeldahl) - -	6·39	3·16	4·93	—	—	165·2	89·0	133·0
Oxygen absorbed from N/8 permanganate at 80° F. :—								
At once - - - -	64·4	259·6	360·8	5·88	51·06	536·9	521·0	450
In 4 hours - - - -	172·5	483·7	583·6	12·25	105·0	729·9	697·0	558
Dissolved oxygen taken up from water at 65° F. :—								
In 3 days - - - -	—	25·2 approx.	—	—	—	—	—	—
In 5 days - - - -	—	54·7 ,,	—	—	—	—	—	—
Chlorine - - - - -	—	—	—	—	—	—	about 570	554
Solids in suspension - - -	—	—	4·0 (4·0 V.)	1·20 (1·20 V.)	7·0 { 5·0 V. 2·0 N.	11·2 { 6·1 V. 5·1 N.	182·8 { 28·0 V. 154·8 N.	75·6 { 21·6 V. 54·0 N.
Solids in solution - - -	—	—	67·2 { 51·4 V. 15·8 N.	73·4 { 19·6 V. 53·8 N.	97·4 { 33·8 V. 63·6 N.	† 1285 { 507·1 V. 777·9 N.	2071·2 { 424·0 V. 1647·2 N.	1903·4 { 480·4 V. 1423·0 N.
Phenols - - - - -	—	—	—	Only about 1·0 if any.	—	—	—	—
Total sulphur - - - -	5·14	(a) *3·46 (b) 2·80	(a) 6·4 (b) —	(a) 5·86 (b) 5·78	(a) 7·19 (b) —	(a) — (b) 202·7	—	—
Sulphur present as :—								
Sulphate (*i.e.*, expressed as S_2)	—	(a) — (b) —	(a) — (b) —	(a) — (b) —	(a) 5·63 (b) —	(a) 19·3 (b) —	—	—
Thiocyanate ,, ,,	—	(a) 0·65 (b) 1·44	(a) 0·0 (b) —	(a) 0·0 (b) —	(a) 0·0 (b) —	(a) 112·0 (b) 109·0	112·0	107·4
Sulphide ,, ,,	—	(a) 0·0 (b) —	(a) — (b) —	(a) — (b) —	(a) — (b) —	(a) 1·0‡ (b) 1·0	—	—
Thiosulphate ,, ,,	—	(a) — (b) —	(a) — (b) —	(a) — (b) —	1·53 (by dif.)	70·1 (by dif.)	—	—
Alkalinity (as H_2SO_4) using litmus paper - - - -	—	—	—	—	—	—	—	12·4
Remarks - - - -	Brown turbid liquid with only a rather small amount of fine brown suspended solids. Cresolic smell.		Clear yellow liquid with some black flocculent solids. Strong phenolic gassy smell. Acid to litmus.	Dark reddish-brown but clear liquid, with a little black suspended matter. Strong gassy smell. The Gooch filtrate from the suspended solids was opalescent.	Brown and turbid liquid with black suspended solids. Dry phenolic odour. The Gooch filtrate from the suspended solids was nearly clear. These suspended solids consisted mainly of coal ash, derived from the overflow from the water seals under the producers, which mixes with the gas liquors.	Very dark brown and turbid liquid, with a little black suspended matter. Strong phenolic smell. The Gooch filtrate was opalescent.	Dark reddish brown in colour, with dark green fluorescence.	Brownish-red with gas smell. Suspended solids grey and finely divided.

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* Too small quantities were taken for estimation of the sulphur compounds. † These continued to lose weight rapidly on drying. ‡ Probably no sulphide.

‖ A duplicate full bottle of this sample was partially analysed on May 18th, 1914, *i.e.* four years after being drawn. As was to be expected, there was little difference between the two analyses, this latter one giving these figures: Ammoniacal nitrogen 0·53; Albuminoid nitrogen 1·70; "Oxygen absorbed" at once 297; "Oxygen absorbed" in 4 hours 463.

on the other hand, the benzol and toluol in the vapour remain uncondensed, and are therefore lost, except for heating purposes. At first, difficulty was caused in the oil tar scrubber by the condensation in it of considerable quantities of chloride of ammonium. We understand, however, that this chloride of ammonium is now removed mechanically with the tar, and recovered from the latter. We are further informed that benzol and toluol are now almost invariably recovered in plants using the direct absorption process.

In the partial direct absorption process, the gases from the coal distillation are cooled to as low a temperature as possible, say, 15° to 25° C., the water carrying the fixed ammonium salts and the tar being thus condensed, while the benzol and toluol are recovered by oil-scrubbing. After passing the scrubber, the gases are heated up again to about 70° C., prior to entering the sulphuric acid saturator, after which they are led to ovens to be burnt. The aqueous liquor holding the fixed ammonium salts must now be distilled with excess of lime in the usual way.

The waste liquids in this case amount to about 25 to 30 per cent. of the coal coked.

Kopper's plant constitutes an example of this process.

To sum up shortly :

It is possible to coke coal and to recover the ammonia without producing much waste liquor.

If, however, benzol, etc., are to be recovered, then waste liquor amounting to 25 to 30 per cent. of the coal results, or it may be as low as 20 to 25 per cent.

In the ordinary processes of making illuminating gas, or of coking coal, with recovery of the ammonia, waste liquor amounting to 50 to 55 per cent. by weight of the coal is produced.

In the *manufacture of producer gas*, something like 10 gallons of waste liquor result from the carbonizing of 100 tons of coal in plants of the Mond type. In many gas-producer plants of this type dilute sulphuric acid is used instead of water in the scrubbers, until the resulting solution of sulphate of ammonia becomes sufficiently concentrated to allow of its evaporation.

Waste Liquor from Coke Quenching.

In all works where coal is coked, water is required for quenching the hot coke, either after its withdrawal from the oven, or in the oven itself. Much of this water is evaporated in the process, but a considerable portion usually flows off. This, after settlement of the fine particles of coke which it has carried away, is generally pumped back for re-use ; apart from solids, this water is comparatively clean.

Gas-holder Water.

Water which has been used as a seal for the gas in gas-holders is a very polluting liquid, which ought never be allowed to escape to a stream.

The analyses in the appended Table (p. 155 A) of a few samples of the spent gas liquor, drawn by our officers at different types of works, will give some idea of its nature.* The samples were :

No. 157. From Colliery No. 71. The spent gas liquor from a coking plant is settled in a series of three small tanks, and is then discharged, together with a large quantity of condenser water, into a river.

No. 189. From Iron Works No. 72. The spent gas liquor, derived from the washing of the blast furnace gases at this works, is partly used for taking dust out of the gases as these pass to the cooling and scrubbing plant.

Nos. 190 and 191. From Steel Works No. 73. The gases from the producer plant at this works are not washed in the ordinary way with water, but are first air-cooled, then passed up a tower down which dilute sulphuric acid trickles, and then strongly cooled in another tower by means of a water jacket. Two kinds of liquor are thus produced, both of the nature of spent gas liquor, viz., a strong liquor, formed by the condensation of water and other vapours in the cooling tower (Sample 190) ; and a weak liquor, produced by the evaporation of the sulphate of ammonia solution under diminished pressure, by means of a water pump (Sample 191). The two liquors are mixed together and discharged into a stream. Sample No. 92 is representative of this general effluent (it contains ash from the water seals under the producers).

No. 06 is a sample of spent liquor from Gas Works No. 74, and Nos. A and B samples of spent liquor from Gas Works No. 75, the second of these being an average sample.

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* The examination of some of these samples had to be deferred on account of other work intervening. Being in full bottles, they underwent practically no change on keeping.

If we consider the six samples of spent gas liquor in the foregoing table—Nos. 157. 189, 190, 06, A and B, we find that, the nitrogen ranged from 3·16 to 165·2 parts per 100,000. The " oxygen absorbed " in 4 hours varied from 172·5 to 729·9; and the (total) sulphur from 3·5 to 202·7 (4 samples).

So far, therefore, as these analyses go, they indicate that spent gas liquors, obtained by different processes and from different qualities of coal, vary greatly as regards strength. Such liquors are always very hard.

Spent gas liquor being comparatively rich in phenol and other germicidal substances, it seemed advisable to make a few experiments in the laboratory, in order to gain some information as to the extent to which it inhibited bacterial oxidation when mixed with (*a*) tap water and (*b*) sewage. For these experiments, three of Dr. Adeney's oxygen absorption apparatus, described in the Fifth Report, Appendix VI., p. 438, were employed.

The sewage available for the purpose was a very weak one, giving the following figures of analysis :—

	Parts per 100,000.
Oxygen absorbed from N/8 permanganate at 80° F. at once - -	1·15
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours - -	5·39
Solids in suspension - - - - - - - - - - - -	11·0
Dissolved oxygen taken up from tap water at 65° F. in 48 hours - -	10·6
Dissolved oxygen taken up from tap water at 65° F. in 5 days - -	17·4

The spent gas liquor (sample No. 189,) taken was that from the Iron Works No. 72, which gave an " oxygen absorbed " figure in 4 hours of 483·7.

The following results were obtained, the figures representing grammes of oxygen taken up per 100,000 grammes of the mixture in question.

Time (days).	*Apparatus I.* 95 c.c. Sewage plus 5 c.c. Tap Water, plus excess of air. Dissolved oxygen taken up :	*Apparatus II.* 5 c.c. Spent Gas Liquor plus 95 c.c. Tap Water, plus excess of air. Dissolved oxygen taken up :	*Apparatus III.* 5 c.c. Spent Gas Liquor plus 95 c.c. Sewage, plus excess of air. Dissolved oxygen taken up :
1	1·2	0·01	0·83
3	2·6	0·27	5·4
5	4·2	0·95	11·7
7	5·9	1·1	—
10	8·2	1·4	19·4
11	8·7	1·4	19·9
15	10·3	1·9	21·7
17	11·3	2·0	22·7
27	13·2	—	24·7
53	15·4	5·3	31·9
71	17·9	6·9	33·0
76	—	7·5	—
95	—	10·9	36·7
109	20·0	14·6	38·0

The figures in the foregoing table show a pretty steady, though slow, absorption of oxygen in all three cases.

I.—The absorption by the sewage pursued a fairly normal course.

II.—In the case of the spent gas liquor, when diluted with 19 volumes of tap water, the absorption proceeded very slowly, though it accelerated as time went on.

III.—In this case, the spent gas liquor, when diluted with 19 volumes of sewage, had, under the conditions of the experiment, apparently no retarding influence on the absorption by the latter ; or, it would probably be more correct to say that the sewage assisted the gas liquor to exert its oxygen absorbing power. At the end of 109 days the absorption in Apparatus III. was slightly greater than in I. and II. together, but not much.

Still, when all is said, the foregoing experiments are sufficient to show that the biological absorption of dissolved oxygen by highly diluted spent gas liquor (a liquor which is capable of taking up oxygen rapidly when it is oxidized by chemical means), even when the dilution is made with sewage, is decidedly slow. In other words, the inhibiting effect of the liquor on the biological purification of polluted water is great.

The spent gas liquor from Colliery No. 71, *undiluted,* showed no absorption of oxygen when kept in an Adeney apparatus for 5 days.

Other experiments on the absorption of dissolved oxygen from water were also made, using different volumetric methods for the determination of the oxygen. The details of these need not be given here, as such volumetric methods are less applicable in the case of spent gas liquor than the direct measurement of the absorption in the Adeney apparatus.

The general results were, however, the same, thus:—

(1) When the Iron Works liquor, No. 189, was mixed with 1·5 to 6 times its volume of sewage and the whole diluted about 100 times with tap water, the mixture took up dissolved oxygen fairly readily.

(2) The results with the Steel Works liquor, No. 190, were confirmatory of the above; the absorption by the liquor when diluted with 99 volumes of tap water was negative, but comparatively rapid when twice its volume of sewage was added.

We have recently supplemented these preliminary trials by further laboratory experiments—extending from June 8th to July 20th, 1914—on the biological filtration of sewage containing known per centages of spent gas liquor.

The biological filter employed was 3 feet 8 inches long by 2½ inches internal diameter, and contained fine (matured) clinker. For these experiments, seven lots of Ealing sewage, each consisting of six half-Winchester quart bottles, were used. Each lot was settled overnight in the ice-box and the liquid siphoned into a pail next morning from the deposited solids. After the siphoned liquid had been thoroughly mixed, it was poured back into clean bottles, to be kept in ice for use as required. A definite quantity of spent gas liquor, varying from 1 to 5 per cent., was mixed with the requisite volume of this siphoned sewage daily, for filtration. The admixture of the liquor with sewage gives rise to a considerable precipitation of solids. These solids (excepting in Experiments A., possibly B., and part of C.), which had meantime collected in the neck of the inverted Winchester quart bottle used as a reservoir, were slowly and carefully poured on to the filter each morning before beginning the day's filtration of the new mixture.

The following table gives some figures of analysis of the siphoned sewages :—

1914.	Parts per 100,000.						
Sample - - - Analysed - - -	A. June 8th.	B. June 12th.	C. June 23rd.	D. June 26th.	E. —	F. —	G. —
Ammoniacal nitrogen -	7·90	5.96	7·00	4·76	Not analysed	8·63	Not analysed
Albuminoid nitrogen -	1·80	1·18	?	1·80		0·46	
" Oxygen absorbed " from N/8 permanganate at 27° C. at once - -	2·70	2·53	2·30	2·73	—	2·89	—
,, ,, in 4 hours	7.62	10·56	6·42	10·30	—	7·02	—
Dissolved oxygen taken up from tap-water at 18° C. in 5 days - - -	13·0	23·8	17·8 (6 days).	27·8	—	21·5	—

These figures show that the sewage was strong in ammonia, but not in carbonaceous matter. Samples E and G, which were not analysed, were of the same general appearance as the others.

The two samples of spent gas liquor used in the experiments, which had the usual reddish-brown colour, gave, on analysis, the figures :—

Parts per 100,000.	No. 1.	No. 2.
Ammoniacal nitrogen - - - - - - - - -	37·4	24·9
Albuminoid nitrogen - - - - - - - - -	33·5	19·0
Total organic nitrogen - - - - - - - - -	95·6	64·1
Total nitrogen (Kjeldahl) - - - - - - - -	133·0	89·0
" Oxygen absorbed " from N/8 permanganate at 27° C. at once - -	450	521
,, ,, ,, ,, in 4 hours -	558	697
Phenol (approximate)* - - - - - - - - -	71·5	69·3
Sulphocyanide, expressed as ammonium salt, NH_4CNS - - -	(*a*) (*b*) 255 ; 222	249
Chlorine - - - - - - - - - - -	554 approx.	570 approx.
Total solids - - - - - - - - - - -	1979 { 502 V. 1477 N.	2254 { 452 V. 1802 N.
Solids in suspension - - - - - - - - -	75·6 { 21·6 V. 54·0 N.	182·8 { 28·0 V. 154·8 N.

It is evident, at a glance, that these two samples of spent gas liquor were very strong.

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* Determined by extracting with ether in the first instance, and finally, after evaporation of the ether, as tri-bromo-phenol.

EXPERIMENT I.—BIOLOGICAL FILTRATION OF SIPHONED SEWAGE CONTAINING 1 PER CENT. OF SPENT GAS LIQUOR, No. 1.

1914. Number of effluent sample	No. A. 2.*	No. A. 3.	No. A. 5.†	No. A. 6.	No. B. 7.	No. B. 8.	No. B. 9.	No. B. 10.	No. B. 11	No. B. 12.
Drawn	June 10th.	June 11th.	June 12th.	June 13th.	June 15th.	June 16th.	June 17th.	June 18th.	June 19th.	June 20th.
Analysed	June 11th.	June 11th.	June 12th.	June 15th.	June 15th.	June 16th.	June 18th.	June 18th.	June 19th.	June 22nd.
Volume of effluent obtained in 24 hours (c.c.)	1150	1267	1710	1120	240 (48 hrs.)	1050	1240	1770	1830	1390
Rate of filtration in gallons per cubic yard per 24 hours	60	67	89	54	6	56	65	92	95	73
Parts per 100,000.										
Ammoniacal nitrogen	0·68	1·52	2·64	2·55	1·3 approx.	0·38	1·05	2·27	3·40	1·34
Albuminoid nitrogen	0·10	0·19	0·27	0·25	—	0·15	0·13	0·23	0·28	0·20
Total organic nitrogen	0·30	1·34	1·61	1·25	—	—	—	—	—	—
Nitrous nitrogen	0·0	0·26	0·40	0·50	—	0·10	0·04	0·08	0·08	0·18
Nitric nitrogen	2·68	2·02	1·48	2·74	2·0 approx.	6·94	7·40	5·60	4·72	7·18
Total nitrogen (Kjeldahl)	3·66	5·14	6·13	7·04	—	—	—	—	—	—
" Oxygen absorbed " from N/8 permanganate at 27° C. at once	0·22	1·50	3·23	3·45	—	0·29	0·32	0·45	0·32	0·47
" Oxygen absorbed " from N/8 permanganate at 27° C. in 4 hours	0·62	2·08	4·10	4·27	3·24	0·84	0·85	1·14	1·01	0·94
Dissolved oxygen taken up from tap-water at 18° C. in 5 days	0·35	0·02	0·57	1·99	—	0·73‡	0·0	0·0	0·42‡	0·0
Incubator test (by smell)	Passed	Passed	Passed	Passed	—	Passed	Passed	Passed	Passed	Passed

Although this was not noted at the times of drawing, all these effluents were yellowish in colour, clear and bright. They had a clean smell and were practically free from suspended solids.

* This sample of effluent was from the filtration of sewage containing *no* spent gas liquor. † All the samples given in this and the following tables were consecutive ones, as is apparent from the dates of drawing. ‡ 6 days.

	EXPERIMENT II.—BIOLOGICAL FILTRATION OF SIPHONED SEWAGE CONTAINING 2 PER CENT. OF SPENT GAS LIQUOR, No. 1.					EXPERIMENT III.—BIOLOGICAL FILTRATION OF SIPHONED SEWAGE CONTAINING 3 PER CENT. OF SPENT GAS LIQUOR, No. 1.					
1914. Number of effluent sample	No. C. 13.	No. C. 15.	No. C. 16.	No. C. 17.	No. C. 19.	No. D. 20.	No. D. 21.	No. D. 22.	No. D. 23.	No. D. 24.	No. E. 25.
Drawn	June 22nd.	June 23rd.	June 24th.	June 25th.	June 26th.	June 27th.	June 29th.	June 30th.	July 1st.	July 2nd.	July 8th.
Analysed	June 22nd.	June 23rd.	June 25th.	June 25th.	June 26th.	June 30th.	June 30th.	June 30th.	July 2nd.	July 2nd.	—
Volume of effluent obtained in 24 hours (c.c.)	139	1690	1400	1920	1565	990	2035 (48 hours)	1630	1780	1130	2994 (7 days)
Rate of filtration in gallons per cubic yard per 24 hours	9	89	74	105	82	52	54	86	94	60	21
Parts per 100,000.											
Ammoniacal nitrogen	—	1·56	—	4·16	3·06	2·08	0·48	1·47	2·39	1·30	0·1 approx.
Albuminoid nitrogen	—	0·32	—	0·24	0·27	0·20	0·25	0·17	0·14	0·21	—
Nitrous nitrogen	—	Trace	—	0·0	0·0	0·04	0·0	Trace	Trace	0·0	—
Nitric nitrogen	—	7·68	—	4·32	6·32	6·36	8·00	6·08	5·36	5·84	—
"Oxygen absorbed" from N/8 permanganate at 27° C. at once	—	0·44	—	0·53	0·35	0·48	0·44	0·49	0·48	0·47	—
"Oxygen absorbed" from N/8 permanganate at 27° C. in 4 hours	—	1·08	1·00	1·14	1·17	1·14	1·14	1·44	1·48	1·29	1·17
Dissolved oxygen taken up from tap-water at 18° C. in 5 days	—	0·83‡	—	0·45	0·27	1·11	0·41	0·72	0·79	0·52	—
Incubator test (by smell)	—	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed	—
Sulphocyanide (as NH_4 CNS)	0·0	—	0·0	0·0	0·0	Trace	0·0	1·0	0·4	—	—
Notes	This consisted mostly of drainings from B. 12.										

No notes were made on the appearance, etc., of these samples at the time of drawing. They were, however, similar to the effluents of Experiment I., only with a more pronounced yellow colour and a little suspended solid. They had a clean wormy smell. ‡ 6 days.

Experiment No. IV.—Biological Filtration of Siphoned Sewage containing 5 per cent. of Spent Gas Liquor.*

1914.										
Number of effluent sample	No. E. 26.	No. E. 27.	No. E. 28.	No. 29. (E. + F.)	No. F. 30.	No. F. 32.	No. F. 33.	No. F. 34.	No 35. (F. + G.)	No. G. 36.
Drawn	July 9th.	July 10th.	July 11th.	July 13th.	July 14th.	July 15th.	July 16th.	July 17th.	July 18th.	July 20th.
Analysed	The dates of analysis were not noted, but they were unavoidably irregular. The samples were kept in ice until analysed.									
Volume of effluent obtained in 24 hours (c.c.)	1970	385	1780	1285 (48 hours)	1840	1890	1815	2015	1670	1610 (48 hours)
Rate of filtration in gallons per cubic yard per 24 hours	At least 103	20	93	34	99	100	95	106	88	42
Parts per 100,000.										
Ammoniacal nitrogen	5·48	6·0 approx.	7·68	7·0 approx.	7·24	—	—	—	—	—
Albuminoid nitrogen	0·86	—	0·48	—	0·58	—	—	—	—	—
"Oxygen absorbed" from N/8 permanganate at 27° C. at once	5·69	—	0·84	—	1·17	—	—	—	—	—
"Oxgyen absorbed" from N/8 permanganate at 27° C. in 4 hours	9·03	2·33	1·87	2·18	4·16	4·20	3·38	3·41	—	—
Dissolved oxygen taken up from tap-water at 18° C. in 5 days	6·84	—	1.95	—	4·98	4·92	4·40	2·12	—	—
Incubator test (by smell)	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Sulphocyanide (as NH_4CNS)†	6·0	1·5	1·0	Mere trace, if any	0	1·0	1·0	1·0	1·0	0

These effluents were distinctly brownish in colour and slightly opalescent (though almost bright after filtration through paper). They had a clean wormy smell, both when drawn and after incubation, though in some cases the odour of the incubated sample was slightly pungent and reminiscent of methylamine. The suspended solids were much greater than in the effluents of the preceding experiments; so far as could be judged by the eye, they amounted to about 4 to 6 parts per 100,000. The effluents gave hardly any froth on being shaken up.

* Effluents E. 26 and 27 were from sewage containing gas liquor No. 1; E. 28 from sewage containing liquors Nos. 1 and 2; and (E.+F.) 29 to G. 36 from sewage containing liquor No. 2.

† The sulphocyanide was tested for at the time the sample was drawn.

In explanation of the foregoing tables it should be said that the effluents A.2 to A.6 were derived from Sewage A, B.7 to B.12 from Sewage B, and so on.

These filtration experiments were done in very warm weather, *i.e.*, under the most favourable conditions in this respect, the temperature (in an adjoining room) ranging between 55° F. and 79° F. during Experiment I; between 61° F. and 77° F. during Experiment II.; between 65° F. and 88·5° F. during Experiment III.; and between 63·5° F. and 81° F. during Experiment IV.

The distribution on to the filter was by drops, the conditions in this respect being good also. It was, however, found difficult always to keep it fairly constant in the earlier experiments, especially at week-ends. The flow averaged :—

Throughout	Experiment	I.	- -	61	gallons per 24 hours.
,,	,,	II.	- -	72	,, ,,
,,	,,	III.*	- -	67	,, ,,
,,	,,	IV.†	- -	77	,, ,,

It is unnecessary to criticise in detail the figures in the tables, which explain themselves, but the results may be shortly summarized as follows :—

The effluents of Experiments I., II., and III. were of a high class and well within the standards of purity recommended by us for sewage effluents in our eighth report.

The effluents of Experiment IV., while all non-putrescible, and all excepting E 26‡ practically free from sulphocyanide, were only of moderate quality and they would not have passed the Commission's standards.

These experiments thus indicate that, in warm weather, settled sewage of moderate strength, and containing up to 3 per cent. of strong spent gas liquor, can be readily treated on a percolating filter at a rate of about 70 gallons per cubic yard per 24 hours. In cold weather purification would no doubt be materially retarded and, besides, out-of-door conditions for filtration are on the whole less favourable than those of the laboratory. Still, we think it may be safely surmised that sewage containing up to 2 per cent. of strong spent gas liquor—a much larger proportion than ordinary town sewages contain—could be successfully treated on a practical scale, always provided that the liquor was fed continuously into the sewage and the mixture distributed on to the filter after a short settlement or septic tank treatment.

It would be desirable to have some quantitative laboratory experiments, similar to the above, made during very cold weather.

Biological Treatment, on a large scale, of Waste Gas Liquor admixed with Sewage.

At Oldbury, near Birmingham, great difficulty was found in purifying the sewage, on account of the admixture with it of about 7 to 8 per cent. of spent gas liquor from a chemical works, although this waste liquor was run into the sewage uniformly. Mr. H. Silvester and, subsequently, Professor Percy Frankland were called in to advise upon the matter, and they carried out a number of experiments at the sewage works, extending, in all, for over a year. A summary of these experiments, together with the conclusions to be drawn from them, is to found in the Fifth Report of the Commission, Appendix IV., pp. 465–9. This was written by Mr. Colin C. Frye, after a visit to the Oldbury sewage works in September, 1906.

A few analyses of the spent gas liquor in question gave the following average figures, among others :—

	Parts per 100,000.
Total nitrogen	56·8
Oxygen absorbed from permanganate at 80° F. in 3 minutes	333·9
Oxygen absorbed from permanganate at 80° F. in 4 hours	499·4
Sulphocyanide (CNS)	153·8
Sulphur as Thiosulphate	46·8
Phenols	140·1

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* Omitting Sample E 25.

† Omitting Sample G. 36.

‡ This effluent had passed through the filter at a *higher* rate than 103 gallons per cubic yard.

The sewage containing this waste liquor was first passed through a septic tank. The septic tank liquor gave the following average figures among others (four sets of samples being included here) :—

Parts per 100,000.				
Oxygen absorbed from permanganate at 80° F. in 4 hours	27·9 (9)*	38·0 (7)	42·1 (4)	37·0 (10)
Sulphocyanide	6·2	10·2	8·7	9·5

This septic tank liquor, when treated in small triple contact beds at the rate of about 50 gallons per cube yard per 24 hours (2·4 fillings per day), yielded a well nitrated and non-putrescent effluent.

When it was treated on large double contact beds at the rate of about 30 gallons per cube yard per 24 hours (1 filling per day) a non-putrescent but not very well oxidized effluent was obtained.

When treated on large triple contact beds at the rate of about 20 gallons per cube yard per 24 hours (1 filling per day), it gave a non-putrescent and well nitrated effluent.

Treatment on large triple percolating filters, at the rate of about 53 gallons per cube yard per 24 hours, likewise resulted in a non-putrescent and well nitrated effluent, though this last effluent was not quite so well oxidized as that from the large triple contact beds.

The general conclusion to be drawn from those experiments was, therefore, that sewage containing about 7 to 8 per cent. of spent gas liquor is capable of biological purification when treated in septic tanks and subsequently—at somewhat low rates—upon either contact beds or percolating filters. But even at so moderate a rate as one filling per day, triple contact filtration was found to be necessary for the production of a uniformly non-putrescent effluent. No exact comparison can be drawn between the results obtained from the contact beds and percolating filters, respectively, as the volumes treated per cube yard in the two cases were dissimilar; the actual amount of oxidation effected on the larger volume of liquor treated by percolating filtration was greater than that on the smaller volume receiving contact bed treatment, but the resulting effluent was not so well oxidized.

The sewage at Oswaldtwistle, in the Ribble watershed, also contains an exceptional amount of spent gas liquor, derived from a gas liquor distillery. The volume has not been accurately gauged, but we understand that it amounts to something like 3 per cent. of the total sewage flow. The sewage is treated in a series of septic tanks and then on percolating filters. We are informed by Mr. Halliwell that the effluent produced is as a rule fairly good, though not of a high-class.

Partial Purification of Gas Liquor.

Dr. Fowler's Process. Treatment of Waste Gas Liquor by Percolating Filtration after Preliminary Dilution with Water.

After experimenting with his colleagues, Messrs. Ardern and Lockett, in the laboratory of the Davyhulme Sewage Works, Manchester, for a number of years, mainly upon the bacterial oxidation of thiocyanates and of phenol,† and in conjunction with Mr. Holton in an out-door experiment at the Manchester Gas Works, Dr. G. J. Fowler was empowered by the authorities to make some large-scale experiments on the treatment of the Bradford spent gas liquor upon already existing biological percolating filters at Frizinghall, Bradford, Yorks. Previous to using the filters for this purpose, he re-inoculated them with an extract of soil, which had been covered with cow dung, and which quickly showed a strong development of nitrate. He informs us that the Bradford Corporation are now (1914) treating the whole of the waste liquor from the Corporation gas works in this way, with a purification of over 80 per cent., as measured by the oxygen absorbed from permanganate in 3 minutes. After prolonged trial he has come to the conclusion that it is better to allow a dilute (though relatively strong as compared with sewage) solution of the liquor to circulate again and again through the filter, rather than to pass a very highly diluted liquor through once.

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* The figures in brackets give the number of samples in each set.

† Fowler, Ardern and Lockett: The oxidation of phenol by certain bacteria in pure culture. *Proc. Roy. Soc. B.* Vol. 83, p. 149 (1910).

Fowler, Ardern and Lockett; Fowler and Holton; and Fowler and Shepherd: *Journ. Soc. Chem. Ind.*, Vol. XXX., (February, 1911).

Fowler, Ardern and Lockett: The influence of waste liquor from sulphate of ammonia plants on the purification of sewage. *Journ. Soc. Chem. Ind.* for May, 1912.

At Frizinghall, about 30,000 gallons of spent gas liquor are treated per day, *i.e.*, this volume of liquor flows in the course of the 24 hours to the small tank (capacity 26,560 gallons), where it is diluted with 9 to 19 times its volume of the gas liquor filter effluent, this mixture being continuously pumped on to the filter. It follows that the continuous discharge of effluent from the filter to the sewers, per 24 hours, amounts likewise to about 30,000 gallons. At week-ends, by which time the liquid circulating through the filter has become too saline, the filters are dosed with clean water occasionally. Success in practice has been found to depend on beginning the filtration with a good dilution (say 5 volumes of liquor in 100 volumes of effluent plus water) and never allowing the feed liquor to get beyond a certain concentration, since it is antiseptic in its action.

The percolating filters (built of clinker of varying size, but covered with a layer, about a foot thick, of material from one-eighth inch to half inch in diameter) have a total capacity of 5,700 cube yards. Consequently the volume of the crude undiluted liquor actually treated is about 5 gallons per cube yard per 24 hours.

The composition of this liquor is approximately :—

	Parts per 100,000.
Oxygen absorbed from permanganate in 3 minutes	448
Oxygen absorbed from permanganate in 4 hours	738
Ammoniacal nitrogen	27·7
Albuminoid nitrogen	18·5

Comparing the average diluted liquor fed on to the filters with the average final effluent discharged, Dr. Fowler finds the respective figures for oxygen absorbed from permanganate in 3 minutes to be 115 and 62. But since only about 30,000 gallons of final effluent are discharged per 24 hours,† the figure 62 must be compared with the 3 minutes figure of the original crude liquor, viz., 450, showing an approximate purification (as judged by this test) of over 80 per cent.

Disposal of Spent Gas Liquor by Evaporation.

In a few cases the spent gas liquor from coke ovens or from power gas plants is entirely evaporated, either by using it along with water for coke quenching, or by means of waste heat in specially constructed evaporators. When worked efficiently, both plans prevent the discharge of any spent gas liquor into streams, but result in local pollution of the atmosphere with vapours which cannot be said to be innocuous.

In the evaporator plants some of the volatile organic constituents of the spent gas liquor are no doubt burnt, but in the quenching of coke there must be much less actual combustion, for in this latter case a volume of dense white steam is produced which may persist for some time in the atmosphere.

On the occasion of a visit by us to a colliery where coke was being quenched with a mixture of water and settled spent gas liquor the steam had a strong phenolic smell. Since it is necessary to use an excess of water in quenching coke, special provision has to be made for collecting the drainage from the quenching floors so that it may be pumped back again for re-use.

So far as our information goes, only four special evaporators are at present in use in England and Scotland. Three are used in connection with blast furnaces at iron works, while the fourth is at a colliery where coke ovens have been installed.

Two works in England and one in Scotland have been inspected either by us or by our officers, and we may describe them very briefly.

At works No. 76, where coal, coke and pig iron are produced, the oven gas is sent through tar extractors, scrubbed with water for ammonia, then with creosote oil for benzole, the residual gas being afterwards used for raising steam along with either blast furnace gas or coal slack, or both of these. The excess of gas from the blast furnace is used for the evaporation of the spent gas liquor. The latter is first settled in tanks and then run into a long narrow brick chamber (approximately 47 feet by 4 feet by 10 feet high, partially divided by a central wall which supports the roof), where it is maintained at a depth of about 12 inches. At one end of this chamber is a firebox, into which the waste blast furnace gas is introduced along with some air and burned, the hot gases passing through the long chamber over the liquor into a chimney stack at the other end. In order to increase the rate of evaporation as much as possible, the liquor is splashed in the chamber by means of two paddles driven by electric motors.

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† Excepting at week-ends, when the filters receive some fresh water, displacing some of the liquid held up.

The evaporator plant deals with from 50,000 to 60,000 gallons of spent gas liquor per day, but it is acknowledged that the plant is being pressed very hard to accomplish this. The less volatile substances accumulate in the bottom of the large chamber as a reddish-brown sticky sludge, which has to be dug out at frequent intervals.

At Colliery No. 77, another form of evaporator is in use. In this case the volume of spent gas liquor is about 20,000 gallons per day. It is first passed through one of two settling tanks, each having a capacity of about 18,000 gallons, and then sprayed into the top of two brick chambers, each 15 feet by 8 feet by 15 feet high, which are strongly bound with iron bands. At the side of the chambers there are furnace boxes, which can be used either for burning waste gas from the coke ovens or coal, or both, the hot gases resulting from the combustion passing up through the evaporating chambers and into a special chimney stack. In order to diminish the rate of depreciation of the brick-work, the inside of the chamber is kept constantly wet with an excess of spent gas liquor which flows away from the bottom of the evaporator and returns to the settling tank. The residual sludge which accumulates in the bottom of the evaporator is dug out from time to time and tipped.

At another Iron works (No. 78) the spent gas liquor is run into old boilers and evaporated by means of the waste gas from a blast furnace. The depreciation of the plant is in this case very high. On the occasion of our visit it was admitted that the plant was not sufficiently large to cope with the whole volume of spent gas liquor produced.

We may conclude our observations on this subject by pointing out the importance of constructing evaporator plants in duplicate, so as to allow of uninterrupted work in the event of a break-down. Where no duplicate plant exists, either the profitable ammonia recovery plant must be stopped when the evaporator breaks down, or the spent gas liquor must be discharged.

In some cases, waste gas liquor from collieries is discharged into old pit workings.

Summary as regards Spent Gas Liquor.

In view of the highly noxious character of waste gas liquor, we are of opinion that in no circumstances should it be allowed to be discharged untreated into a stream.

When it is produced at gas works in a town and does not at any time exceed 2 per cent. by volume of the sewage, it may without serious detriment to the subsequent purification of the sewage be allowed into the sewers, always provided that there is sufficient tank capacity at the gas works where the gas liquor is produced to ensure that it shall flow into the sewers equably, and, as far as possible, continuously, and not in flushes. At certain sewage works the biological efficiency of the tanks and filters has on occasion been seriously affected by an unexpected flush of this liquor. It must exert, of course, the same prejudicial effect upon the working of a sewage farm.

When the spent gas liquor, before being discharged to the sewers, is subjected to partial purification, a larger relative volume may be mixed with the sewage. We are not aware of any method of partial purification which is fairly successful, other than that suggested by Dr. Fowler; and this, we think, would probably prove more expensive than combined treatment of the gas liquor with sewage, where sewage was available.

As at most collieries there are large spoil heaps, we recommend that these should be used for the purification of the spent liquor by percolating filtration, as in the case of the "bings" at the Shale Oil Works in Mid and West Lothian. This may not in all cases result in a satisfactory effluent, but considerable purification will always be effected where large spoil heaps exist.

Where there are no spoil heaps, we can only suggest, as an alternative at the present moment, the evaporation of the liquor.

With the exception of the filtration of the waste liquor from shale distilling works through "bings" of spent shale, which must be regarded as a somewhat special case, we know of no method by which spent gas liquor can be purified at reasonable cost to such an extent as to render it innocuous if discharged into a stream. There are consequently no data to show what degree of purification might reasonably be asked for. Further work on the subject is thus required, in order to prevent or diminish the serious injury to streams which is at present taking place in certain districts.

GENERAL SUMMARY AND CONCLUSIONS.

91. The foregoing account of the more important trade processes which produce waste liquids contains the data which we have been able to obtain in regard to the composition of the various liquids and the means which are available or might, in our opinion, be made available for the treatment of those liquids.*

We find, however, that the information which we have collected cannot without further legislation be employed to the best advantage, and we have, therefore, thought it proper to give some fuller consideration to the questions arising out of our inquiry, with a view to suggesting improvements in administration and amendments of the existing law.

THE EXISTING LAW IN REGARD TO MANUFACTURING POLLUTION.

92. The Rivers Pollution Prevention Act, 1876, embodies the following main principles in regard to pollution caused by manufacturing † processes.

The offence created by the Act is the discharge into a stream of "any poisonous, noxious or polluting liquid." Where the discharge is along a channel used, constructed or in process of construction at the time of the passing of the Act, or a channel used in substitution thereof, an offence is not committed if it is shown to the satisfaction of the Court that the best practicable and reasonably available means are being used to render the liquid harmless. In all other cases the prohibition as to discharging any poisonous noxious or polluting liquid is absolute.

In the case of most manufacturing processes a strict compliance with the terms of this prohibition would be impossible. The Act, however, imposes on the taking of proceedings certain limitations which operate for the protection of the manufacturer. It provides that

(*a*) Proceedings shall be taken only by a sanitary authority. [By the Local Government Act of 1888 concurrent powers of taking proceedings were conferred upon County Councils and Joint Committees of County Councils. These powers we find are exercised but little, if at all, by many sanitary authorities and County Councils, and systematic enforcement of the law for preventing pollution is only undertaken in those few areas for which Joint Committees or other bodies have been expressly constituted for the purpose.]

(*b*) Proceedings shall not be taken without the consent of the Local Government Board.

(*c*) The Local Government Board in giving or withholding their consent shall have regard to the industrial interests involved in the case and to the circumstances and requirements of the locality.

(*d*) In any district which is the seat of a manufacturing industry the Local Government Board shall not give their consent unless they are satisfied that means for rendering harmless the trade liquid are reasonably practicable and available in all the circumstances of the case, and that no material injury would be caused to the industry by such proceedings.

(*e*) In the case of such manufacturing districts, notwithstanding any consent of the Local Government Board, the person against whom proceedings are proposed may appear before the Sanitary Authority and object to such proceedings—the Sanitary Authority being required to have regard to the same considerations as the Local Government Board in determining the case.

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* It must be understood that the trade liquids to which reference is made in what follows are those which for any reason cannot be taken into public sewers, but are discharged direct into streams.

† A distinction is drawn between manufacturing and mining pollutions, and the latter are considered separately. See next paragraph.

(*f*) No proceedings shall be taken until the expiration of two months after written notice of the intention to take proceedings. (It has been held that the consent of the Local Government Board must precede such notice—West Riding Rivers Board *v.* Robinson—76 L.J., K.B., 426 (1907); 1907. 1, K.B. 43.)

(*g*) No proceedings shall be taken while other proceedings for the same offence are pending.

(*h*) A person against whom proceedings have been taken cannot be proceeded against by any other authority until he shall have failed in reasonable time to carry out the order of the Court.

(*i*) The County Court before which proceedings are taken has a wide discretion as to the form in which an order may be made. The judge may simply prohibit continuance of the offence or may prescribe the works to be carried out and the conditions under which they are to be carried out. Before making such order he may remit to skilled parties to report on the " best practicable and available means " and the nature and cost of the works and apparatus required, and such experts shall in all cases take into consideration the reasonableness of the expense involved.

(*j*) A certificate of an inspector appointed for the purpose by the Local Government Board to the effect that the means used for rendering harmless the liquid in question are the best or only practicable and available means under the circumstances of the case shall be conclusive evidence of the fact. The Local Government Board on appeal against the granting or withholding of the certificate may confirm, reverse or modify the inspector's decision.

The Law as to Mining Pollution.

93. The Rivers Pollution Act deals separately with mining pollution, but on lines generally similar to those on which it deals with manufacturing pollution. Some points of difference, however, deserve to be noted. The discharge of solid matter from a mine in such quantities as to interfere prejudicially with the due flow of the stream is prohibited. The discharge of any poisonous, noxious or polluting solid or liquid from a mine is also made an offence, but subject to the same qualification as in the case of trade effluent outlets existing at the time of the passing of the Act, *viz.*, that it is not deemed an offence if the person discharging can satisfy the Court that he is using the best practicable and reasonably available means to render the matter harmless.

Rivers Pollution Prevention Act, 1876, Sec. 5.

A further point of difference in the law relating to mines is that water in the same condition as that in which it has been drained or raised from the mine is specifically excepted from the operation of the section. This is a special exemption of considerable importance; it does not, however, affect the general question of procedure, and we shall refer to it later in the report.

DEFECTS OF THE EXISTING LAW.

94. From a study of these provisions, and of the evidence which has been laid before us as to their operation, we have come to the conclusion that they are open to objection on two main grounds. On the one hand, they provide facilities for escaping the consequences of the commission of an offence; and, on the other hand, they do little to assist manufacturers who are anxious to avoid the offence itself.

Both these defects seem to us to be fundamental and inherent in the principle on which the law is conceived. If we leave out of account the provisions in regard to channels existing at the date of the Act—provisions designed to prevent hardship arising from its retrospective operation—and the similar provisions in regard to mining pollution, we see that the law makes a prohibition with which most manufacturers could only comply to the letter by closing their works. In the case of most trades there are no practicable means of securing that no poisonous, noxious or polluting liquid whatever is discharged into the stream. The law does not say that a manufacturer who is using the best practicable means of treatment is not committing an offence, it merely provides him with means for escaping prosecution.

95. The commission of a technical offence being practically inevitable, it was clearly judged necessary that some safeguards should be provided to protect the manufacturer who does his best to avoid committing an actual offence. These safeguards are, as we have seen, sufficiently elaborate. The prosecuting authority must obtain the consent of the Local Government Board, who are bound before giving it to be satisfied on various points. When that consent has been obtained, the authority must give two months' notice before proceeding, and, in the meantime, the manufacturer may demand that the authority shall hear his objections and decide upon them in a more or less judicial capacity, and finally the Court might find on expert advice that any effective order would be impracticable on the ground of expense.

96. This prolonged procedure affords ample opportunities for evasion to an actual offender. On the other hand, it gives little or no guidance to the manufacturer who is ready to avoid causing pollution but is ignorant of the best means of doing so, nor does it give him any security that when he has constructed works to comply with present demands he will not be compelled thereafter to comply at short notice with further and more stringent demands.

We do not suggest that the authorities who are empowered to enforce the Rivers Pollution Acts are in the habit of pressing their provisions unduly, but we do suggest that it is desirable to secure that a manufacturer shall know with what degree of purification the authorities will be satisfied and for how long they will be satisfied with that degree.

97. We think that a good deal could be effected in this direction by a simple alteration of the provisions quoted above. It is to be observed as a rather curious feature of the Act of 1876 that whereas the Local Government Board are required to have positive knowledge of industrial and local requirements, their functions are of a merely negative character. They may be compared in this respect to a Grand Jury—they can stop further proceedings, but when once they have given their consent to proceedings being taken the matter passes out of their hands. Thus their knowledge of the local conditions is not available at the time when it is most required—that is when it has to be decided by the Court what particular steps are necessary to prevent a recurrence of the offence.

It appears to us to be a not unreasonable proposition that if the Local Government Board are the body best qualified to decide on the merits of a particular case that proceedings are to be taken, they are also the body best qualified to determine what action should be taken if the proceedings are successful.

98. The considerations which, under present conditions, are to guide the Local Government Board in the first instance are, broadly speaking, the same as those which are to guide the experts to whom the case may be referred by the County Court in the last instance. But whereas a Central Authority may be expected to observe a uniform principle in their decisions, the various County Courts and the various experts might well hold widely divergent views of local and industrial requirements. We suggest, therefore, that procedure would be at once shortened, simplified and made more uniform if some alterations in the law were made. We think that these alterations might be designed so as to provide :

(1) that before proceedings are taken against a manufacturer the Rivers Board or Sanitary Authority should specify the degree of purification which they propose to demand ;

(2) that the manufacturer should have the right of appeal to the Central Authority against those requirements ;

(3) that the requirements when agreed to by the manufacturer or settled by the Central Authority should remain in force for a definite term of years ; and

(4) that on proceedings being taken for infringement of the requirements any matters at issue (other than questions of law) should be referred by the Court to the Central Authority.

STANDARDS FOR TRADE EFFLUENTS.

99. We think that such alterations as we have indicated in regard to procedure would be effective in obtaining both a greater measure of security for the manufacturer, and a greater measure of uniformity in administration. But further advance in both directions is in our view desirable. The discretion which would be given to the Central Authority by our proposals would doubtless be exercised within more definite limits than the discretion which is now given to the different County Courts and the expert advisers whom they

may consult. But it would strengthen the hands of the Central Authority and at the same time be more satisfactory both to the prosecuting authorities and to the manufacturers if general rules in regard to the degree of purification to be demanded as regards various trade wastes could be formulated and published. It is further desirable that such rules should have the force of law binding on the Courts. Unless these rules were made statutory they might have little effect; for example, if a Sanitary Authority were to obtain the necessary consent and take proceedings on the ground that the agreed or approved requirements were not being fulfilled, the Court might find that, whether those requirements were in fact being fulfilled or not, an offence against the Rivers Pollution Act was being committed, and might make an order which had no reference to such requirements. To obviate this result it is necessary that offences against the Act should be further defined, and this could best be done by reference to a standard or system of standards, provision being made to the effect that the discharge of a trade effluent which complied with the appropriate standard of purity should not be an offence against the Act.

THE PRACTICABILITY OF GRADUATED STANDARDS FOR TRADE EFFLUENTS.

100. In regard to the purification of domestic sewage by local authorities, we advocated in our Eighth Report a single standard which could be modified in various local circumstances. We have now to consider whether and to what extent the principles which we laid down in regard to sewage can be made to apply to trade effluents, having regard to certain differences which exist in the character of sewage and of trade effluents and in the conditions under which they are respectively discharged.

Differences in Character of Sewage and Trade Effluents.

101. The several classes of trade waste show *inter se* much greater differences of character than do the various types of sewage liquids. Indeed, as compared with trade wastes, sewage liquids may be regarded as more or less homogeneous; and from this point of view sewage pollution is but a single species of pollution—each kind of trade waste appearing as a parallel but quite distinct species. Hence it would be unsafe to assume that measures which are applicable to the regulation or prevention of sewage pollution are necessarily applicable to the case of trade pollution, or to legislate for trade pollution generally without distinguishing between the different conditions affecting different trades.

102. The scheme of standards which we recommended for sewage liquids was based upon prolonged and extensive observation of the effects which various sewage liquids of known composition and volume had upon various streams of known character and volume. By carrying out experiments and observations under a great variety of local conditions we aimed at eliminating or discounting irrelevant factors, and isolating, as far as possible, the effects which are directly attributable to the discharge of the sewage liquids under review. Before we could recommend, with equal confidence, a similar scheme of graduated standards for trade effluents, we should need to investigate the different effects produced under different local conditions by each class of trade waste. So extensive an inquiry we have been unable at the time at our disposal to attempt. It must be remembered, too, that no single kind of trade liquid is discharged under so great a variety of local conditions as is sewage, and that in industrial districts, where the question of trade pollution is most serious, it frequently happens that different trade liquids are discharged at such short intervals and are so intermingled that separate estimation of their effects is impracticable.

Different Effects of Sewage and Trade Pollutions upon Fish Life.

103. We find that, speaking generally, manufacturing pollutions are apt to be more injurious to fish life than is sewage pollution. The effect upon fish of a discharge of sewage liquor is produced in the main not directly but through the de-oxygenation of the water, owing to decomposition of organic constituents of the liquor. Trade liquids, on the other hand, may not only de-oxygenate the water but they may contain constituents which are directly poisonous to fish. The Royal Commission on Salmon Fisheries reported in 1902 that:

> "Many manufactories discharge substances which are directly toxic. Among these are the chlorine from bleaching works, paper works, etc., the acids from steel works and tin plating works, the alkalis from wool washings, the gas lime, cyanides and carbolic acid from gas works, and the organic acid in the pot ale of distilleries. . . .
>
> "The fine detritus of coal washings may act as an irritant to the gills of the fish, and by forming a deposit in the river bed prevents the free passage of oxygen to the ova."

We agree with this statement, and we find also that some trade liquids contain mineral poisons such as arsenic, lead and zinc, which are undoubtedly harmful to fish. For example, we have found the following amounts present (in parts per 100,000):

In 6 dye and bleach works effluents	0·01 to 0·26	Arsenic (As).
In 2 chrome tannery effluents	0·38 and 2·13	,,
In a brook water above a print and dye works	0·02	,,
In a brook water below a print and dye works	0·07	,,
In a brook water near a works manufacturing arsenical products	7·6	,,
In a dye and bleach works effluent	0·24	Lead (Pb).
In a lead mine effluent	·66	Zinc (Zn).

We are unable to say what would constitute a toxic dose of any of these substances; our evidence shows that further investigation is needed into the effect upon fish of different mineral poisons. While dilution with comparatively clean water may be relied on to prevent injurious de-oxygenation, we have no information showing to what extent such dilution would be a safeguard against the effect of poisonous substances.

104. In the present state of our knowledge, therefore, we do not think it possible to found a scheme of graduated standards for each class of trade effluent on any adequate basis of observation and experiment *in regard to the effect of trade pollutions on streams.*

Differences in regard to Methods of Treatment of Sewage and Trade Refuse.

105. For sewage liquids there are several known methods of treatment, by a selection or combination of which the required degree of purification may be obtained. For many trade wastes, on the other hand, only one method of treatment is known or needed; for others, there may be available two or three processes, each producing somewhat similar results, while in other cases no means of treatment are at present known which could be made efficient at any reasonable cost.

From this point of view graduation of standards for each class of trade waste seems neither necessary nor desirable.

Differences in General Conditions Affecting the Discharge of Sewage and Trade Wastes.

106. There is, moreover, a broader distinction between sewage and trade discharges which should have some bearing on the administrative aspects of the question. The discharge of sewage is a public necessity, its proper disposal is a public duty carried out by a public authority at the public expense. Provided that this service is efficient in the sense of preventing injury to the river and to the community, any saving which can be effected on this head is to the direct interest of the community and should be encouraged on public grounds. On the other hand, the disposal of trade waste by a manufacturer is part of a process which he voluntarily carries on for his own profit. We do not suggest that he should be penalised on this account, but we think it not unreasonable to expect that a trader who uses water from a stream for his own purposes should do what he can towards returning it to the stream in a condition as pure as it was before use, even though owing to the relative volume of the stream the discharge of unpurified waste would cause no appreciable injury. Nor do we think that a trader who derives his water from other sources could properly complain of a similar requirement, for he is not compelled to discharge into the stream but only uses it as a convenient method of getting rid of his waste liquids; we hope, however, that in future the difficulty will be solved in the majority of these cases by the reception of the effluents into the sewers of the local authority.

107. Arguments have been put before us in favour of requiring, as far as is practicable, the same degree of purification from all who are competitors in the same branch of trade. We think it generally desirable to aim at securing uniformity of treatment for those engaged in any given branch of industry rather than at providing for preferential treatment in those cases where merely local conditions would seem to warrant a relaxation of the ordinary requirements.

Tod and Toyne, 28781–92: Leach and Marshall, 28919–23: Hanson, 29418: Whitaker 29447–8.

108. We are then in favour of the principle that any standards which may be prescribed for the purification of trade wastes should be determined rather by the character of the particular trade waste to be treated and by the means available for treating the particular waste than by the local conditions under which it is discharged. At the same time we

have not lost sight of the fact that under existing conditions many manufacturers are so placed that they would have much greater difficulty in complying with any given standard than would others engaged in the same industry; in some cases indeed, owing to want of space or for other reasons, they might find it impossible to comply with the standard. Again, when for any reason it is necessary to preserve a very high degree of purity in a river, a more stringent standard than would be required in normal circumstances might have to be prescribed.

109. We think that for each branch of industry a single standard of purity should be prescribed by the Central Authority, and that a departure from that standard should only be permitted if the Central Authority are satisfied on the merits of the particular case that it is necessary in the interests of the manufacturer and the locality.

A SINGLE STANDARD FOR EACH CLASS OF TRADE WASTE.

110. We have now to consider to what extent it is possible in the present state of our knowledge to indicate standards which would be appropriate to each class of trade liquid.

The Rivers Pollution Prevention Commission, appointed in 1868, recommended certain standards or limits of impurity for effluents generally.* These recommendations were embodied in the Bill for the Public Health Act, 1872, but were withdrawn during its passage through Parliament. They were again embodied in the Pollution of Rivers Prevention Bill of 1873, which failed to become law.

In our opinion some of their requirements were and are too stringent for general adoption. It would be impracticable for the majority of manufacturers to comply with them, not only on account of the great development of manufactures and the difficulty of obtaining land, but mainly because the subject has not even yet been sufficiently investigated.

111. We think it impossible to lay down, as regards each trade, such a standard as would ensure the complete purification of rivers, since, in the present state of knowledge, the attainment of such a standard would in many cases be financially impracticable and therefore useless. We have thought it useful, however, to suggest limits of impurity which we believe to be now practicable, and which are based upon careful consideration of the data given in the detailed sections.

These figures will afford guidance to the Central Authority when established, and, although provisional and based upon the present condition of knowledge, they should, in our opinion, if prescribed, remain in force for a definite period. At the end of this period they would be subject to revision, since admittedly they are inadequate to prevent pollution of streams, and improved methods of treatment may meanwhile have been discovered.

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* These were :—

(*a*) Any liquid which has not been subjected to perfect rest in subsidence ponds of sufficient size for a period of at least six hours, or which, having been so subjected to subsidence, contains *in suspension* more than one part by weight of dry organic matter in 100,000 parts by weight of the liquid, or which, not having been so subjected to subsidence, contains *in suspension* more than three parts by weight dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b*) Any liquid containing, *in solution*, more than two parts by weight of organic carbon, or 0·3 part by weight of organic nitrogen in 100,000 parts by weight.

(*c*) Any liquid which shall exhibit by daylight in distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d*) Any liquid which contains, *in solution*, in 100,000 parts by weight, more than 2 parts by weight of any metal except calcium, magnesium, potassium and sodium.

(*e*) Any liquid which, in 100,000 parts by weight, contains, *whether in solution or in suspension*, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

(*f*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine.

(*g*) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition of either sulphuretted hydrogen or of soluble sulphuret.

(*h*) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i*) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

(*k*) Any liquid exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing, in suspension, in 100,000 parts, more than ·05 part of such oil.

112. In regard to the periods for which standards for sewage effluents should remain in force we made the following suggestion in our Eighth Report:—

> (52) We think it of importance that a standard once imposed upon a local authority should not be altered until the expiration of a definite period, in order that they may have some security as to the extent of their liability.
>
> We suggest that these periods should be prescribed by Order of the Central Authority, and should in the case of the general or any specially stringent standard be not less than ten years from the date when the standards came into operation. In the case of relaxed standards the periods should be shorter. The less elaborate the plant required to meet a standard, the less hardship there will be in reducing the period during which the standard should remain in force; and, on the other hand, it is desirable to offer the local authorities some inducement, in the shape of a more prolonged immunity from interference, to carry purification beyond the minimum. By the end of those periods the Central Authority should have acquired sufficient experience to enable them to decide whether the general standard required any modification (which we suggest they should be empowered to effect by the issue of an Order), and also to revise, where necessary, the special standards in particular cases.

We think the Central Authority might well consider whether a similar principle might not be applied to standards for trade effluents, viz., that in the case of those trades where a standard involving expensive plant is prescribed, the period might be longer than in those where only partial means of purification are as yet known. In the latter case the period could of course be extended if in the meantime no improved methods of treatment had been discovered.

SUGGESTED STANDARDS FOR DIFFERENT KINDS OF TRADE WASTE.

113. We think it important that, in order to simplify administration, the standards to be prescribed for different classes of trade wastes should be uniform with one another as far as practicable. While it is recognized that different trade liquids have widely divergent effects upon streams and cannot always be judged by the same tests, it has been urged that such common characteristics as they possess should be made amenable to the same standard. Representations have been made to us that in all trade liquids the suspended solids (which may be regarded as common to them all) should be reduced to the same figure.

114. We are aware that this uniformity of standard cannot produce uniform results either as regards cost to the manufacturer or as regards the effect upon streams. The separation of solids is a much more costly process in some trade liquids than in others, and this is a consideration which cannot be wholly disregarded. Again, the suspended matters in some trade liquids have a much more deleterious effect than the same quantity of solids in other liquids; but it is obvious that this discrepancy diminishes as the amount of solids allowed to pass into the stream decreases.

115. The crux of the problem lies in the figure which is selected as the standard. It has been strongly represented to us, on behalf of existing Rivers Authorities, that this figure should not exceed 4 parts per 100,000 for all trade liquids. We should welcome the imposition of such a standard if we were satisfied that it could be met at reasonable cost. Evidence has been brought before us with a view to showing that suspended solids can be reduced to this degree. But we think it necessary to point out that the procedure which we propose to recommend differs in some important respects from the procedure at present adopted for the enforcement of the Rivers Pollution Prevention Acts. River Authorities, under existing conditions, exercise a wide discretion in instituting proceedings under the Acts, and they must needs exercise discretion in the absence of a more definite guide than "the best practicable and reasonably available means." On the other hand, the manufacturer desires to know more definitely what is required of him. This he will gain from the setting up of a standard; but the converse of this proposition is that a standard once set must be rigidly adhered to. We do not suggest as a general rule that prosecution should follow a single infringement of the standard, but we contemplate that in the event of prosecution a single infringement should transfer the burden of proof to the manufacturer. Hence a standard thus rigidly enforced cannot be set at a figure which can only be reached under the most favourable conditions. If a manufacturer is liable to be judged by his worst results he must for his own sake aim at producing *average* results which are better by a considerable margin than the prescribed standard. It follows that under the system which we contemplate any standard which we may suggest will in practice be much more stringent than would appear at first sight.

116. It will be seen that in the case of most trade liquids under review we propose a standard for suspended solids of 4 parts per 100,000, but in some cases we do not feel justified in suggesting so stringent a standard, because we are not satisfied that it could be *uniformly* attained at reasonable cost. We cannot disregard the economic aspect of the problem, and we feel that while too lax a standard will fail of its results, too stringent a standard will fail in its inception, and the failure will discredit the whole principle of standards which it is our object to establish.

117. At the same time it must be borne in mind that our suggestions are far from being intended as a final pronouncement on river purification. We look forward to a time when improved methods will secure generally a still greater measure of purification, and in the meantime we would point out that under the system which we propose it will be open to any Rivers Authority in specific cases where they are satisfied that a higher degree of purification is either attainable or has in fact been regularly attained, to require a higher degree of purification than we have indicated for particular trades, if they can satisfy the Central Authority that it is necessary and practicable.

118. We find that the different kinds of waste liquids may be classified under the following heads:

(A) Those for which efficient purification is practicable;
(B) Those for which efficient purification is not in the present state of knowledge practicable.

119. In Class A, we include waste liquids resulting from:

(i.) Coal washing.
Tin mining.
Lead and zinc mining.
China clay works.
Stone quarrying.
Stone polishing.
Wood pulp paper works.

In all these cases adequate reduction of solids in suspension may be regarded as efficient purification.

(ii.) Brewing.
Malting.
Distilling.
Tin plating.
Galvanizing.
Wire drawing.
Shale oil distillation.
Woolscouring.
Tanning.
Leather dressing.
Fellmongering.
Dairying.

In these cases dissolved impurities should also be removed.

120. In Class B, we include waste liquids resulting from:

(i.) Bleaching.
Waste bleaching.
Paper works (except where paper is made from wood pulp only).
Cotton dyeing.
Cotton printing.
Woollen dyeing.
Woollen piece and yarn scouring with dye liquor.

(ii.) Sulphite cellulose manufacture.
Gas and coke production.

Although no practicable means are known for rendering completely harmless the liquids included in this class, nearly all of them can be and are considerably improved by clarification.

We have placed sulphite cellulose liquor and spent gas liquor in a separate sub-division because we are not aware of any method of so treating them that the effluents could properly be discharged direct into streams.

Class A.

121. (i) In this sub-division, as we have pointed out above, reduction to a low figure of the solids in suspension may be regarded as efficient purification, and this can be effected by adequate settlement.

Coal Washing.—We think that the effluent should not contain more than 4 parts of suspended solids per 100,000. In a number of cases this standard might have to be relaxed. Page 12.

Tin, Lead and Zinc Mines, China Clay Works, Stone Quarries, and Stone Polishing Works.—Here we suggest provisionally a standard of 6 parts suspended solids per 100,000. So far as our evidence shows, reduction of suspended solids to this extent should obviate danger to cattle or fish from poisoning by lead, tin, antimony or arsenic. Pages 14, 17, 18, 21.

There are, however, cases in which no interests other than those of the particular industry are affected by the discharge of the waste waters. If it can be shown, *e.g.*, in the case of small streams near to the sea, which are not used for fishing, for navigation, for watering cattle, or for manufacturing purposes, that no damage is caused by the discharge of waste waters without treatment, we think that the standard might be relaxed or wholly dispensed with.

Paper Mills where wood pulp alone is used.—In this case the effluent should not contain more than 4 parts suspended solids per 100,000. Page 91.

122. (ii) In this sub-division, reduction of dissolved as well as suspended impurities is necessary.

Breweries and Maltings.—We suggest that the effluents should contain not more than 4 parts per 100,000 suspended solids and should take up not more than 4 parts per 100,000 dissolved oxygen in five days. Pages 115, 116.

Distilleries.—For the various methods of treating this waste, we refer to our Sixth Report. Since the issue of that Report we have kept under observation plants which were erected on the lines which we recommended, and have found them both efficient and economically practicable. We recommend a standard of 3 parts suspended solids and 2 parts dissolved oxygen absorption in 5 days. (This corresponds with the general standard which we have suggested for sewage effluents.) Sixth Report.

Tin Plating, Galvanising and Wire Drawing.—These wastes are strongly acid from mineral acid and contain much iron in solution. The stronger liquids should not in any circumstances be allowed to discharge into streams. The wash waters should be neutralized and settled. Page 122.

We suggest that the standard for these wash waters should be 6 parts per 100,000 suspended solids.

Even after compliance with this standard, a somewhat yellow and colloidal liquid might result. It might possibly have to be softened before discharge, but we do not think it necessary at present to suggest any standard of hardness.

Shale Oil Distillation.—The standards which we suggest are 4 parts per 100,000 suspended solids and 4 parts per 100,000 dissolved oxygen absorption in 5 days. Page 153.

Woolscouring Liquor.—Though the precipitation liquor, obtained by subjecting woolscouring liquor to direct precipitation, is practically free from fat, it remains very strongly organic and may be regarded as similar to a highly concentrated sewage liquor; and the same may be said of the septic tank liquor from wool suds, which also contains much sulphuretted hydrogen. Pages 106-108.

For this reason we consider that the liquor should be looked upon as a sewage and purified biologically. This treatment has so far only been carried out in the laboratory, but we are of opinion that it is practicable at a reasonable cost, and, subject to our conclusion being verified by experiments on a large scale, we recommend a standard of 4 parts suspended solids and 4 parts dissolved oxygen absorption in 5 days.

Pending such experiments we would suggest, for this type of precipitation liquor, clarification down to 6 parts of suspended solids per 100,000.

Tannery Waste, Leather Dressers' Waste and Fellmongers' Waste.—These wastes are also highly polluting and contain much organic matter of animal origin in solution. Our observations in regard to the treatment of wool suds are equally applicable to these wastes, and we make a similar suggestion in regard to a standard, viz., 4 parts suspended solids and 4 parts dissolved oxygen taken up in 5 days. Pages 127, 140.

Dairy Waste.—Here, too, our observations on wool suds are applicable. We suggest as a standard 4 parts suspended solids and 4 parts dissolved oxygen absorption in 5 days. Page 147.

Class B.

123. We now come to that class of trade waste in regard to which we are not in a position to say that efficient means of purification (such as would render them "harmless") are reasonably practicable and available. As we have said, however, some of them (Class B (i),) are, according to present knowledge, capable of being considerably improved, and it will be useful to indicate to what extent improvement has been found to be practicable.

Page 51. (i.) *Bleaching.*—In this waste the polluting matter is mainly in solution, but some improvement would be effected by reduction of suspended solids. We suggest that it should not show more than 6 parts suspended solids.

Systematic experiments on a large scale would be necessary before suggesting any standard based on the absorption of oxygen.

Page 51. *Waste Bleaching.*—The waste liquor from this trade is of the same nature as that from bleaching, but it may contain a good deal of soap in addition. We suggest a standard of 6 parts suspended solids per 100,000. Systematic experiments on a large scale are also required here.

Page 90. *Paper Works* (*Esparto and Rag Paper—Esparto and Wood Pulp Paper*).—The liquid portion of most of these wastes is, as a rule, considerably weaker than that of bleach wastes, but we have found one instance where it was equally strong (owing probably to a less abundant water supply).

Here, too, systematic experiments on a large scale are necessary. In the meantime we can only suggest a standard similar to that proposed for bleach wastes, *viz.*, 6 parts suspended solids.

Page 97. *Paper Works* (*Brown Paper and Wall Paper*).—For the waste liquors from these works we think that a standard of 6 parts of suspended matter would suffice at the present time.

Pages 28, 41. *Cotton Dyeing and Cotton Printing.*—Compared with many other wastes, these are not very polluting, but their volume is large. Although most of their oxygen absorbing power is due to dissolved impurities, considerable improvement is effected by clarification.

We suggest as standards, 4 parts suspended solids for cotton dye liquor and 6 parts for the liquor from print works.

Pages 59, 68, 79. *Woollen Dyeing, Piece and Yarn Scouring and Blanket Scouring Liquors* (*occurring either separately or in any combination*).—Though these wastes are not usually concentrated, their liquid portion is, as a rule, of an oxygen absorbing and putrescent nature. Clarification produces considerable improvement. As a standard, we suggest 4 parts suspended solids per 100,000.

Pages 71, 78 79. *Wool Scouring, with Piece and Yarn Scouring and Dye Liquors.*—Wool scouring liquor or wool suds when unmixed with other wastes forms the subject of a later paragraph. It is an exceedingly polluting liquid, and when it is combined with those discussed in the preceding paragraph it adds considerably to their strength.

If, however, all four liquors, as produced together at the works, are carefully mixed, it is possible to obtain, with the aid of good precipitation, a non-putrescible effluent which does not take up oxygen at an excessive rate.

The standard which we suggest is 4 parts suspended solids.

Page 118. 124. (ii). *Manufacture of Sulphite Cellulose.*—So far as we are aware, there are only two works in this country from which either the waste liquid produced by this process or the more dilute washings are discharged into a steam. We are unable to suggest a standard appropriate to the waste liquid, but we think that neither the liquor itself nor the first washings should be discharged into a stream.

Page 164. *Spent Gas Liquor*—Here, too, we are unable to suggest a limit of purification. In no circumstances should the liquor be discharged untreated into a stream. In some cases purification by percolation through "bings" may be sufficient to permit the discharge of an effluent, but we can make no general pronouncement on the point. Where no bings exist, biological treatment on the lines suggested by Dr. Fowler will lessen very materially the polluting power of the liquor. Evaporation appears to be the only other practicable alternative at the present time.

125. The information which we have set out above is obviously incomplete. It does not extend even to all existing trade processes whereby polluting liquids are produced, though it includes the most important. And it is to be anticipated that new processes will continually be coming into operation and creating a demand for new means of purification—a demand which could not be efficiently forestalled by any system of standards which we could suggest.

126. We do not, therefore, recommend that the Central Authority should forthwith proceed to prescribe a complete set of standards for all known kinds of trade waste, but we think it eminently desirable that a general standard should be prescribed in all cases where its efficacy and practicability have been in some measure tested by experience. We are confirmed in our view inasmuch as the West Riding of Yorkshire Rivers Board, the Mersey and Irwell, and the Ribble Joint Committees, and the Thames Conservancy Board have progressively employed for their own guidance working rules which are in the nature of standards. It will however be necessary to consider the prevention of pollution both by existing and by new processes for which no standard can as yet be fixed.

127. In the case of some trade wastes, additional standards may have to be imposed, *e.g.*, standards of hardness and of "caustic" alkalinity or acidity, or a requirement of neutrality, for the effluents from various branches of the cotton, woollen and paper trades and from metal works; a standard for arsenic or other poisonous metal for trades in which those substances are used or mined; an oil-film standard for the wastes from oil, gas, grease or soap works, etc. Some further investigation may be required before such standards—or some of them—can properly be laid down.

These standards should, in our opinion, be looked upon for the most part as *special* standards, applicable only to certain rivers or reaches of rivers where local circumstances call for them. It is important, however, that the necessity for imposing them in special cases should be borne in mind when the *general* standard is being considered, for in some cases the special standard may be required more urgently than the general standard. Several manufacturers have, for instance, urged that the "softness" of a river water is of greater moment to them than its organic purity. It will be necessary, also, to have special regard to the protection of drinking waters against mineral poisons.

ALTERATION OF EXISTING LAW.

128. We may now set out in greater detail the proposed amendments of the existing law which have been foreshadowed in the earlier sections of this Report. We recommend that the law should be altered so as to provide as follows:—

1. The Central Authority may by Order prescribe a general standard for effluents produced by any trade process therein defined, the standard to remain in force for a period to be specified in the Order. The Order shall be published in the *London Gazette*, and a copy of it shall be sent to every Rivers Board, County Council, and Sanitary Authority.*

2. Where a general standard has been thus prescribed, the authority before taking proceedings shall serve a notice on the manufacturer specifying the requirements of the general standard and the period within which the requirements are to be complied with. After the expiration of that period, proceedings may be taken against him for non-compliance with the notice (but on no other ground†), and the consent of the Central Authority shall not be required to such proceedings. The proceedings should not be taken in a County Court for an order, but in a Court of Summary Jurisdiction for a penalty. The Court may extend the period in which the requirements are to be complied with, and if they consider that it is doubtful whether the notice can reasonably be complied with they shall remit the question to the Central Authority who shall confirm or modify or cancel the requirements, and who may fix a period during which the requirements as confirmed or modified shall be in force or shall be cancelled as the case may be. The Central Authority may from time to time extend such period, but on the expiration of the period the requirements of the general standard shall be deemed to be again in force in regard to the works in question.

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* This expression includes Rivers Boards, County Councils and Joint Committees of County Councils.

† *i.e.*, not on the ground that he is discharging a "poisonous, noxious or polluting liquid", but only on the ground that his effluent infringes the particular standard.

3. Where no general standard has been prescribed, the authority, before taking proceedings, shall serve a notice on the manufacturer specifying the degree of purification which they propose to require, certifying that means are available for meeting their requirements and prescribing the period within which their requirements are to be met. Within one month of the service of the notice, the manufacturer may appeal to the Central Authority against the notice. If he does not appeal, proceedings may be taken against him after the expiration of the prescribed period as if the requirements of the notice were a general standard in force in regard to his works.

If he appeals, the Central Authority shall confirm or modify or cancel the requirements of the Sanitary Authority. If the Central Authority confirm or modify the requirements, such requirements as confirmed or modified shall be deemed to be the standard in force in regard to the works of that manufacturer for such period as the Central Authority shall specify. The Central Authority may also extend the period within which the requirements must be complied with and on the expiration of such period as prescribed or extended, proceedings may be taken without the consent of the Central Authority for the recovery of a penalty for non-compliance with the standard in force. If the Central Authority cancel the requirements for a period, no proceedings shall be taken within that period.

4. Where a general standard has been prescribed, but for any reason the authority propose to require of any manufacturer a higher degree of purification than is required by the standard, the authority shall also set out in the notice the requirements of the general standard and the reasons for requiring the higher degree of purification. In all other respects, the procedure shall be as if no general standard were in force.

5. The authority shall be required to prepare an annual report on the administration of the Rivers Pollution Prevention Acts within their jurisdiction, including particulars of all requirements made by them under the Act, whether appealed against or not, and to submit a copy thereof to the Central Authority.

6. Where a Rivers Board is constituted for any area, the authority for the purpose of enforcing the Rivers Pollution Prevention Acts in that area shall be the Rivers Board. The order constituting the Rivers Board shall provide for the adequate representation on the Rivers Board of any fishing interests concerned.

7. Where no Rivers Board has been constituted, the authority for the purpose of enforcing the Rivers Pollution Prevention Acts shall be the County Council, who should act through a Rivers Committee, and the Central Authority may, by Provisional Order, confer or impose upon the Rivers Committee any powers or duties of a Rivers Board, including the co-optation of representatives of any fishing interests for the said purposes.

NEW SOURCES OF POLLUTION.

Atter, 27167.

129. Representations have been made to us that the law should be altered with a view to the prevention or regulation of the establishment of new sources of pollution. It has been suggested that every person who proposes to set up works whereby liquid refuse might be discharged into a stream should be required to give notice of his intention to the Sanitary Authority or Rivers Board, specifying what steps he proposes to take to prevent such liquid refuse from polluting the stream; that the Sanitary Authority or Rivers Board should have power (subject to appeal to the Central Authority) to disapprove the proposals; and that any person failing to give notice or commencing to discharge liquid refuse after his proposals have been disapproved should incur a penalty.

We are fully in sympathy with the object of taking measures in advance for the prevention of pollution, but we think that the suggested procedure might involve needless interference with manufacturers. We do not, therefore, recommend that the law should be altered except to this extent—that the manufacturer proposing to establish new works from which liquid refuse would be discharged into a stream should be required, under penalty, to give to the Rivers Board as long notice as possible, and at least a month's notice, before commencing to discharge. The Rivers Board would then indicate to him the degree of purification which would probably be required of him.

We do not think that a penalty other than for failure to give notice or for actual infringement of a standard should be imposed.

POWER OF ENTRY.

130. We repeat the recommendation contained in Paragraph 59 of our Eighth Report, which we think should extend to entry on the purification works of manufacturers.

> (59). We think that the Officers of the Central Authority and of the Rivers Boards should have statutory authority to enter upon lands at any time without notice for the purpose of inspecting works and rivers and taking samples of the liquor or effluent and river water wherever they can be obtained. The Rivers Pollution Prevention Act, 1876, contains no provision on this subject, but reference may be made to Sections 16 and 17 of the Alkali Works Regulation Act, 1881, Section 98 of the Thames Conservancy Act, 1899, and Section 7 of the Middlesex County Council Act, 1906. In the Mersey and Irwell Joint Committee Act, 1892 (Section 10) and the West Riding of Yorkshire Rivers Act, 1894, the power to take samples is limited to the point at which the effluent enters the stream. We think this limitation is undesirable.

We recommend further that manufacturers should be required under penalty to provide facilities for taking samples of effluent at the point or points where it leaves their premises.

MINE WATER.

131. We have already referred to the exemption which is conferred by the Rivers Pollution Prevention Act, 1876, in regard to waters proceeding from any mine "in the same condition as that in which it has been drained or raised from such mine." We are not aware of the circumstances to which this exemption was due. We have received some evidence of the pollution caused by some mine waters of this character, which, in many cases, continues after the mine has ceased to be worked. But our evidence is not sufficient to enable us to make any general recommendation in regard to preventing this form of pollution. Under the system which we have suggested, it would be open to a Sanitary Authority to demand purification of such waters subject to appeal to the Central Authority, who would be able to consider each case on its merits.

THE NEED FOR FURTHER EXPERIMENTS.

132. In this and in previous Reports, we have repeatedly drawn attention to the need for continuous and systematic research in all branches of the wide subject with which we have been called upon to deal. Our labours have extended over a period far exceeding the customary span of a temporary Commission, yet we have been unable to explore many fields that are known to require investigation. Were we to continue our labours until we had covered all known fields of inquiry, we should still be faced with fresh problems arising out of social, industrial and scientific developments. We have recommended, in the constitution of a Central Authority, the setting up of permanent machinery for carrying on the work of investigation, and we would express the hope that if there must be an interval before this machinery can come into operation, there will be devised some method, not requiring legislation, by which research can in the meantime be continued on the lines which we have indicated in our several reports.

Further investigation is needed in regard to the treatment and disposal both of sewage and trade wastes. We are aware that local authorities, manufacturers and others conduct experiments from time to time in regard to particular points of difficulty, but we are impressed with the need of some independent authority which could not only test and co-ordinate the results of such experiments, but would itself seek the solution of problems which individual enterprise has not yet attacked. We are convinced that in this way great improvement in sanitation concurrently with substantial economies could be secured, and we are, therefore, confident that the co-operation both of local authorities and manufacturers can be relied on to give aid of great value in the work of progressive research.

II.—THE DISPOSAL OF LIQUID AND SOLID DOMESTIC REFUSE IN RURAL AREAS.

133. The word "sewage" is not defined in our terms of reference. By etymology and by common acceptance sewage means refuse in more or less liquid form—that which is drained away. Further, it has been held that a drain becomes a sewer when it drains more than one building, and by Section 13 of the Public Health Act, 1875, all sewers, with certain exceptions, vest in the local authorities. Hence, sewage is generally understood as being the product of a water carriage system, and, more precisely, of a water carriage system which is under the control of a public body. In the course of our inquiry we have treated the problems of domestic sewage disposal as problems arising out of a public system of water carriage for which the local authority rather than the individual is responsible.

134. For the removal of excremental matter from aggregations of houses, the water carriage system is in this country the most generally adopted, the most convenient and the least offensive method. Owing to a variety of reasons, however, the system is not and cannot be universally adopted, and we, therefore, feel it our duty to include some reference to other methods of dealing with domestic refuse, solid or liquid, which, if not in strictness methods of "sewage" disposal, are alternative ways of attaining the same essential object.

135. We have examined the following witnesses in regard to this question:

Dr. G. V. Poore, Professor of Medicine at University College, London;

Dr. H. Franklin Parsons, late Assistant Medical Officer to the Local Government Board;

Dr. H. Handford, County Medical Officer of Health for Nottingham;

Dr. G. E. Scholefield, Medical Officer of Health to the West Lancashire Rural District Council;

Dr. J. R. Prior, Medical Officer of Health, West Berks Combined District;

Mr. William Seamark;

Mr. William George;

Professor E. V. B. Harley, M.D. (Edin.), M.R.C.P., F.C.S.;

Dr. G. Herbert Fowler.

136. It is generally agreed that if a water carriage system is to prove satisfactory there are two chief desiderata: (1) that an ample water supply should be laid on to the houses; and (2) that houses should not be so scattered that the cost of sewerage is prohibitive.

In places where the water supply is deficient, waste water closets are sometimes employed, *i.e.*, closets which are flushed by household slops instead of fresh water. There is considerable evidence to show that the working of these closets is generally accompanied by objectionable results and we cannot recommend them.

When sewers are not available cesspools may be utilised. If these are water-tight the difficulty of disposing of their contents is not solved but only postponed; if not, danger may arise from their leakage to water supplies in their neighbourhood.

137. In the absence of both water supply and sewerage, recourse must be had to some form of "dry" or "conservancy" system in which excrement is not carried away from houses by water, but is stored in their vicinity for a longer or shorter period.

We have heard evidence from several witnesses on various modifications of this system. All are agreed, and we strongly support their view, that methods of this kind are not suitable for towns or villages where the population is more or less dense. Conservancy systems still obtain in certain parts of some of our great towns, but notwithstanding the efforts which have been and are being made to minimise the dangers attendant on a "dry" method by the systematic provision and collection of properly constructed movable receptacles, these systems are in such cases open to grave objection. We may point to the evidence of the late Dr. Parsons as to the difficulty of disposing of the excrement when collected, and as to the serious risk of spreading infection through the spilling and treading about of the contents and through the agency of flies and dust. 32957–32978.

138. In country districts, however, where the population is so scattered that the provision of a public water supply or public sewerage is difficult or impossible, some conservancy method is practically the only method which can be adopted. It will be useful briefly to consider the comparative advantages and disadvantages of some of the forms which are commonly in operation.

There are many types of conservancy closet differing from one another both in construction and in use. We do not think it possible to make any general pronouncement as to which is the best type, since the requirements and the available facilities differ in different localities. One of the main distinctions between different types is that between closets which have fixed and those which have movable receptacles.

Closets with Fixed Receptacles.

139. These closets, in their worst form, that of the old-fashioned privy midden, which from its large size, encourages the reception and accumulation during long periods of all kinds of filth, the liquid contents of which soak into and pollute the soil while the remainder pollutes the atmosphere, are condemned by their mere description. They may, however, be much improved if they are made so small as to necessitate frequent emptying, and if their walls and floors are constructed of impervious material to prevent soakage. It is important, too, that they should not be sunk below the ground level, in order that they may be more easily and thoroughly cleaned. Ashes should be applied to the excreta in order to mitigate the offensiveness, and liquid and other house refuse should be kept separate. If the privy is so used it is known as a privy ashpit.

140. Of closets with fixed receptacles the best form would appear to be some kind of earth closet. This need not differ in construction from a privy of improved type; the difference lies in the use of earth to cover the excreta. If the earth is of suitable quality, dried under cover, and duly applied whenever the closet is used, it not only neutralises offensive smell, but has a nitrifying and resolving effect upon the excreta, and thus both improves the manurial value and considerably reduces the offence attendant on storage in the neighbourhood of dwellings. Constant supervision, however, is needed to ensure the regular use of suitable earth; and, as Dr. Parsons has pointed out, it would be difficult to enforce bye-laws requiring an earth closet to be kept supplied with dry earth. 32998.

Closets with Movable Receptacles.

141. The commonest form of this type of closet is the pail closet. In towns where a pail system is employed on a large scale under the control of the local authority, the pails may be provided with antiseptics and deodorants or with absorbent linings or other devices to minimise nuisance, but in country districts ordinary pails without any special preparation are most commonly in use. The great advantage of this type of closet is that their contents can be easily removed without soiling the ground and must be frequently removed owing to the small size of the receptacle. 33121-2. Dr. Handford, County Medical Officer of Health for Nottingham, expressed the view that in small communities, where there is no public scavenging, a privy midden, constructed according to the model bye-laws, is preferable to a pail on the ground that it does not cause so much nuisance from a moderate degree of neglect. 33242-3. On the other hand, Dr. Prior, Medical Officer of Health for the West Berkshire Combined District, took the opposite view that the effects of an over-full pail being more obvious would demand more speedy attention.

142. An earth closet may also be constructed with a movable receptacle, in which case it has the same advantages over an ordinary pail, as it has when the receptacle is fixed, over a privy. If it be fitted with a movable receptacle and the excreta are properly and regularly covered with dry earth, an earth closet is generally regarded as the best available substitute for a water closet from the point of view of cleanliness and convenience.

Interim Report, Vol. II. 143. Whatever the type of closet employed there arises the problem how to dispose of the contents when removed. Dr. Poore, whose works on the subject are well known, gave evidence before us in regard to an experimental system which he had carried out for many years for the disposal of excremental refuse from his cottages. He urged that admixture with water should be avoided as far as possible in order to retard putrefaction, and that putrescible refuse should be treated in the upper layers of cultivated soil. He recommended that that fæcal matter in the pails should be collected *daily*, dug into shallow trenches and covered with soil. Cabbages, he said, should first be dibbled into the ground so prepared, and afterwards any suitable crop might be raised. He found that the excrement thus treated had considerable manurial value.

144. This method of disposing of excrement can be successfully employed either with fixed or with movable receptacles, provided that adequate garden ground is available in the immediate neighbourhood. We heard the evidence of two cottagers who found no difficulty in disposing satisfactorily of their privy contents about once a week. If, however, no garden is at hand, the householder must get someone else to remove the 33294-33386 refuse. Farmers will sometimes undertake this, but, as a rule, only at infrequent and irregular intervals when they happen to need the material. A system of public scavenging is generally the best solution, although it usually meets with local opposition for the reason that there is no power to recover the cost from the householders who benefit by it, and the charge must be shared by ratepayers who can dispose of their own refuse. If, however, public scavenging is adopted, the advantages of a movable receptacle become obvious. We cannot too strongly insist that, whatever the ultimate destination of the excrement, the main point to be aimed at is the frequent removal of such refuse from dwellings without allowing it to be spilt, and this we think is best secured by the provision of small movable receptacles.

145. It must, however, be borne in mind that no form of "dry" system is adequate to deal with the whole of the refuse from a house; there will always be a certain volume of liquid refuse to be disposed of. This volume will depend on the water supply available. If the supply be limited, the waste water may usually be disposed of on the garden by Interim irrigation after a simple method of straining such as Dr. Poore suggests, or be collected Report, Vol. II. in a small sump and applied to the garden by hand. Fruit trees in particular, it is said, are benefited by these liquid wastes. Even this plan is, however, liable to break down in times of heavy rain, especially when the soil of the garden is of an impervious nature.

146. But as soon as an abundant supply of water is piped to dwellings the consumption of water increases enormously, and the problem of dealing with waste liquids increases in proportion. Their volume then becomes too great to be dealt with on limited garden space. In that case it will be necessary, in the absence of sewers, to resort to a cesspool. If the contents of a cesspool can soak away without risk of polluting water supplies no harm may be done; but if, as frequently happens, it is necessary for the protection of underground water supplies to make the cesspool water-tight, it must be emptied at more or less frequent intervals. From figures supplied by Dr. Parsons, it would appear that 33037-33042. the recurring cost of emptying cesspools may be considerable, and the question arises whether in some cases a system of sewerage might not be provided at no greater cost.

147. Dr. Handford has shown that it is possible to provide sewage disposal works on a small scale at a very reasonable cost. He gives instances of works costing from £150 Vol. II., to £500 to serve populations of 200 to 400. It appears, however, that, as in the case of p. 60. public scavenging, under the present system of rating many persons may be compelled to share the cost of a scheme from which they can derive no direct benefit, and it is not surprising that promising schemes have frequently to be abandoned owing to the opposition of such persons.

148. We do not think it is necessary for us at the present day to labour the advantages of an efficient water carriage system. Apart from its merits on the score of hygiene, it carries with it what to most people is the strong recommendation of removing responsibility from the individual and saving him personal exertion. It possesses, moreover, the indirect advantages of involving a public water supply, the benefits of which cannot seriously be disputed.

149. Conversely, the existence of an abundant water supply in a rural district seems to us almost necessarily to involve sewerage and water carriage. Nevertheless, there are probably cases in which rural communities, sparsely populated, with widely separated dwellings, have been saddled with the expense of a sewerage system without sufficient consideration being given to possible alternatives.

150. The evils arising from improper management of a dry system are so numerous and patent that they are often regarded as inherent in the system. Many of the disadvantages of the dry method disappear if dry closets are properly constructed, if their contents are disposed of with care, and at regular, frequent intervals.

In some rural districts, where the houses are so scattered and all have adequate garden space, a dry system is practicable, may be more economical than water carriage, and prove satisfactory under careful superintendence.

151. The argument against a public water carriage system is often not a sanitary, but an economic one. In rural districts, even where there is an abundant water supply, the houses may be widely scattered, and the cost of a sewerage system too great. In such cases cesspools may be a practical alternative where there are no local wells and no water supply will be prejudiced by leakage from them.

Witnesses concerned with sanitary administration were, however, emphatic in their 33215. preference for water carriage where practicable, and Dr. Scholefield held that, where the water supply was sufficient, water closets, even when connected with cesspools, are superior to any dry method of excrement disposal,

Where there is no danger of polluting water supplies, the cesspools may be constructed of open material, allowing leakage to the soil, provided they are placed sufficiently far from dwellings; in such cases, if the soil be suitable, they will not require or will rarely require to be emptied.

152. There are many villages, however, where there is only a scanty supply of water, where the supply is not carried by pipes within the houses, but where the householder is obliged to fetch it from standpipes outside, or even to pump it from a well. In such cases, even where the supply is ample, the quantity of water used is much limited by the labour of obtaining it. With a water supply so limited that water closets are insufficiently flushed, there is much to be said for the adoption of some sort of dry system. In these districts the cottages have usually sufficient garden space and generally little difficulty arises as to the disposal.

The householder in his own interests and those of his neighbours should attend to the removal and distribution over his garden of the excreta and domestic waste waters. But in regard to the latter it is found in practice that the women of the household, especially in wet weather, are apt to pour them out as near the scullery door as possible, leaving them to flow in improper directions, and often into the roadway. There is room for much educational work in these matters, and local authorities should bring useful information to the notice of householders, as, for instance, Dr. Poore's method of distributing the domestic waste waters over the garden.

CONCLUSIONS.

153. *In rural areas the main fact governing the question of the removal of excremental matter and domestic waste waters is the abundance or the scarcity of the water supply.*

(1) With an abundant water supply, piped to the houses, water carriage is, in our opinion, the most satisfactory system. In most cases abundant water supply will involve a system of sewerage. Where there are isolated dwellings which it would be very costly to connect with the drainage system of the district, the cesspool is a possible alternative, where there is no danger of polluting water supplies.

Under the Public Health Act, local authorities have a discretion in regard to compelling connection with their sewers. We think it right that with their local knowledge they should have this discretion. The storage and disposal of excreta is a matter concerning a man's neighbour as well as himself.

(2) Where a water carriage system is impossible because of the inadequate water supply, we believe that under proper supervision, a system of dry closets may be open to little objection on sanitary grounds, provided the closet is so constructed that its contents can be conveniently and frequently removed, as by the use of pails.

In small communities the removal may generally be left to the householder. In larger villages it may with advantage be undertaken by the local authority.

The domestic waste water is best distributed over the gardens, or it may be conveyed to a cesspool, as far as possible from the dwelling, if no water supplies are prejudiced by the leakage from them.

In villages where no sewers are available, it is desirable that cottages should be provided with ample garden space for the disposal of domestic refuse.

The use of dry earth in dry closets is of great importance, and local authorities should be given full power to secure its use.

Local authorities should also circulate to householders elementary information as to the best method of dealing with refuse over their gardens.

One of us, Sir William Ramsay, is not in full agreement with the views expressed in this part of our Report, and has therefore drafted a separate Memorandum on the subject which is appended to this Report.

154. The Commissioners cannot close their long labours without expressing their high appreciation of the valuable services of the two gentlemen who, at different periods, have acted as Secretaries to the Commission.

For twelve years that position was held by Mr. F. J. Willis, upon whom fell the task of preparing the first six reports of our Commission, and who, since he gave up his duties as Secretary, has been of great assistance as a member of the Commission.

For the later period our Secretary has been Mr. R. H. H. Keenlyside, who was responsible for the drafting of our Seventh, Eighth, Ninth and Final Reports.

We desire also to record the great value of the able assistance we have received from our technical staff, especially from Dr. McGowan and Mr. Colin Frye, our expert chemists, and from Mr. G. B. Kershaw, our engineering adviser. We would also wish to mention with gratitude the help we have had from Dr. A. C. Houston on all matters relating to bacteriology. In the earlier years we also had the assistance of the late Professor Sir Rubert Boyce.

Their wide knowledge of the subject with which we had to deal and their devotion to the work of the Commission have much contributed to the results of our enquiry.

The junior staff has also acted loyally, and we would desire to convey our thanks to these gentlemen, several of whom have aided us by special investigations. The names of the junior staff and their periods of service are :—Dr. A. MacConkey (1899–1901) ; Miss Harriette Chick (1901–1905) ; Mr. R. B. Floris (1899–1905) ; Mr. R. S. Finlow (1900–1903) ; Miss Power (1902–1905) ; Miss Hartley (1902–1914) ; Mr. E. H. Richards (1903–1913) ; Mr. A. C. Carter (1903–1914) ; Mr. A. F. Girvan (1905–1911) ; the late Mr. W. G. Winterson (1906–1910) ; Mr. E. C. Barfield (1910) ; and Mr. G. T. P. Tatham (1910–1914).

Valuable work was also contributed from time to time by the following gentlemen, viz. :—Dr. W. E. Adeney, Dr. H. Gordon. Dr. A. S. F. Grünbaum, Dr. C. A. Hill, Professor E. A. Letts, Mr. R. D. Littlefield, Mr. T. H. Middleton, Dr. E. J. Russell, Professor W. Somerville, Mr. R. A. Tatton, and Dr. J. A. Voelcker.

We also desire to thank Mr. A. E. Goddard, of the Local Government Board, and Mr. Hollingsworth, our Clerk, for the efficient discharge of their clerical duties.

We further wish to express our indebtedness to the Mersey and Irwell Joint Committee, the Ribble Joint Committee, and the West Riding of Yorkshire Rivers Board, and to the many local authorities and their officials and to manufacturers who have, throughout our inquiry, rendered us very valuable assistance.

The Appendix to this Report, containing the Minutes of Evidence taken on the 100th to 107th days and the results of special investigations made by some of our officers and others, will be published in a separate volume.

IDDESLEIGH, *Chairman.*
T. WALTER HARDING.
WILLIAM RAMSAY.*
W. H. POWER.†
T. J. STAFFORD.
R. A. TATTON.
F. J. WILLIS.

R. H. H. KEENLYSIDE, *Secretary.*
February 11th, 1915.

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* Subject to the Memorandum on page 184 on the disposal of domestic refuse in rural areas.

† Subject to the Memorandum on page 189 on certain administrative questions.

MEMORANDUM BY SIR WILLIAM RAMSAY, K.C.B., F.R.S.

At one of its early meetings (on May 21st, 1901), the Commission took evidence from Dr. Vivian Poore, the Professor of Medicine at University College, London, on the disposal of refuse in villages, and from country houses. At a much later date (November 22nd, 1911), Dr. Franklin Parsons, late Assistant Medical Officer to the Local Government Board, Dr. H. Handford, County Medical Officer for Nottinghamshire, Dr. George Edward Scholefield, Medical Officer of Health to the West Lancashire Rural District Council, and Dr. J. R. Prior, Medical Officer of Health for the West Berks Combined District, gave evidence before the Commission; and on the same date, two labourers, tenants of Dr. Harley, Professor of Physiological Chemistry at University College, told us of their domestic experience in disposing of the sewage from their own little houses. Dr. Harley also gave his experience as regards the orders which he had been obliged to carry out, against his scientific knowledge, owing to the local regulations of the district in which he resides.

When it is considered that according to the Census of 1911, a considerable proportion of the inhabitants of England and Scotland, and a larger proportion of the inhabitants of Ireland live under rural conditions, I feel strongly that the final Report of this Commission should contain some suggestions as to the proper methods of disposal of sewage under such conditions. According to the Census returns of 1911, 60 per cent. of the inhabitants of Great Britain and 25 per cent. of those of Ireland live in "towns." But it must be noted that the outskirts of towns contain houses which are really in the "country"; also, that many villages have a "town" population, living in terraces and streets. It is, therefore, impossible to estimate the relative number of the population living under rural conditions, but the number is by no means insignificant.

It may be well to begin with a sketch of the various plans of disposal, some of which are very ancient and inefficient, but which persist owing to the inertia of the people.

A "privy" is a small chamber in which the excreta and the urine are received in a rectangular box, or it may be on the floor of the chamber, and accumulate there. Owing to leakage, the urine generally drains away, leaving the fæces and paper to accumulate. This chamber is generally outside the dwelling house; it is emptied only when the accumulation of filth has grown to such an extent that the place can no longer be used. Such a method of disposing of sewage stands self-condemned, and requires no further comment here.

A "pail-closet" differs from a "privy" in so far as the fæces and urine do not fall on the floor, but into a pail placed to receive them. It has this advantage, that it must necessarily be emptied at shorter intervals, and the filth has therefore less time to accumulate. Moreover, it is much easier to remove a pail than to dig out the accumulations in a privy.

An "earth-closet" differs from a "pail-closet" inasmuch as earth is sprinkled on the fæces, either by hand with a shovel or by some mechanical device. This is, or should be done immediately after using the closet.

A "privy-midden" is to all intents a "privy," except in so far as the place is utilised for the disposal of household refuse; ashes, potato parings, cabbage stalks, and, in short, all the matter thrown away from the house. A "privy-ashpit" differs from a "privy-midden" by being made the receptacle only of excreta, urine and ashes, but not of all kinds of household rubbish; its contents are supposed to be dry except for the urine which necessarily enters.

These methods of disposal imply that no water is used to wash away the fæcal matter. Where water is used the "cess-pool" or "cess-pit" comes into operation. This is a deep pit in the ground; local regulations insist on its being so cemented as to be water-tight, hence, if properly made and maintained, there should be no leakage, and, as it is covered, no evaporation can occur. The drainage of the house, fæcal matter, urine, slops, scullery-water, bath-water, etc., all may find their way into the cess-pool, which sooner or later becomes full. This involves emptying and getting rid of the filthy semi-fluid mass. It is either a costly or a very disagreeable operation, and there is always great difficulty in disposing of the refuse without annoyance from stench. As a matter of experience, in spite of regulations, cess-pits are rarely tight; it is the almost universal custom to make a hole in the cemented bottom so that the liquid portion of the filth may soak away into the soil. It is obviously not an easy task for a local authority to ascertain whether or not a cess-pit is tight, and, indeed, the task would be a most unsavoury one.

Needless to say the inspector turns his blind eye on cess-pits, and, so long as no outbreak of disease occurs, sleeping dogs are allowed to lie. A cess-pit may be defined as a practically permanent septic tank, emptied only at long intervals, or, if leakage takes place, probably not at all. No doubt a certain digestion of the solids occurs, but no experiments have been made on the subject so far as I am aware.

Having now given a short description of the various methods of sewage disposal where no drainage system exists, I shall next summarise the evidence which has been brought before us.

First,—our witnesses are unanimous in asserting that such methods of disposal of sewage are not applicable to towns, at least, where the houses are massed together and not surrounded by gardens (32956). In such cases a drainage system is indispensable. In this I fully concur. Dr. Parsons also confirms our conclusions that (32978) under present conditions (that is, when allowed to accumulate in cess-pools; or after it has been buried in deep trenches) night soil from towns is of little value as a manure; it does not pay to carry it to where it might prove of value; moreover, " you couldn't furnish a supply of earth to a town " (32975—*see also* 33080–33086).

Second,—the witnesses vary in their estimates of the relative advantages of pail-closets, earth-closets, and privy-ashpits. Dr. Parsons, for example, strongly recommended dry-closets of an improved form, which at one time he used himself, disposing of the contents on his garden. He advocates earth-closets, but points out that an earth-closet when used without earth becomes a privy, and there is no power of making a by-law which shall require an earth-closet to be supplied with earth, although it is possible to insist on a water-closet being supplied with water. Dr. Parsons states that it is now possible to proceed against a householder for " potential nuisance," that is, if he keeps his premises in such a state that there may result harm to himself and his neighbours. Dr. Handford thinks that for

> " Houses with six or eight or ten rooms a cess-pool is necessary, and in the very large majority of instances, certainly in Nottinghamshire, the cess-pools are never emptied, because, although they are made professedly water-tight when they are constructed, they never remain water-tight more than a few months; in a year or two they all leak."

Dr. Handford goes on to say that there is no objection to their leaking provided they are so placed as not to contaminate any water-supply.

These cess-pools have, however, nominally to be emptied; where there are no cess-pools it has been found that people will not take the trouble to look after the disposal of their refuse on their gardens; they will not keep the fæcal matter separate from the ashes and kitchen refuse, and, therefore, in many instances, the services of a public scavenger have been called in. This necessitates dealing with the filth on a large scale, carrying it by rail or by barge, when its receptacles may leak, and the stuff, too, grown very foul by reason of age. Dr. Handford therefore recommends even in very small communities a water-closet system, and in an appendix states that the cost of sewage disposal works in the Basford Rural Sanitary District varies between £150 and £500. This does not include the cost of drains for the houses, an expense which must be very considerable.

Dr. Scholefield, dealing with the various methods of disposing of sewage other than by water-carriage, gives the preference to the " privy-ashpit " (33215). Although it is always desirable to mix ashes with the fæcal matter, that is not always done; but there is no difficulty (33211) either in disposing of the refuse to farmers or in using it for the gardens attached to the houses. For some time this required propaganda, but people told each other and at present the state of affairs is quite satisfactory. Where there is a public water supply bath water is emptied on the gardens; only a few houses have water-closets which discharge into cess-pools along with the bath water; even in such cases the householders utilize their wash water for irrigation. Dr. Scholefield remarked that the threat of an expensive sewerage scheme being forced on them was effectual in inducing these communities to pay attention to their own sanitation. His evidence may be summed up in his own words:—

> " I think you can manage to get people to do better by teaching them that it is very much to their own comfort and to their own health to keep the premises in a cleanly condition than to allow things to go too far and so become dirty and disagreeable."

Dr. Prior's experience agrees with Dr. Scholefield's. He thinks that where the population is scattered " the dry closet is unquestionably better." He issues printed instructions and follows them up by visits and inspections; the fæcal matter is emptied daily into a trench and covered up with earth. This is easily done by the master of the house. When asked :—

> "Then you have solved the problem of getting people to do as you tell them," he answered, "Partially so, Sir." "Is it spreading?" "Undoubtedly it is improving; it requires a very great deal of real looking after by the Sanitary Inspector to start them."

He points out that public scavenging is expensive; it puts 3d. or 4d. on the rate; for a £20 house, 5s. a year. He deprecates the erection of privies or privy-middens in connection with new buildings; he prefers the use of a pail-closet, a zinc pail costing only 2s. and lasting several months; "there is never any difficulty in procuring earth."

Mr. Seamark and Mr. George gave the Commission very racy evidence, dealing with their weekly burying of refuse in their gardens. They stated that this took only a few minutes, and that it gave them better vegetables; their slop-water runs into a ditch and causes no nuisance. The inhabitants of the twenty houses in their hamlet keep their places "all clean and respectable," and the inspector never interferes with them. They have plenty of water, but have to fetch it from a stand-pipe in their gardens. Householders with a family have to empty their "places" (they do not use pails) more than once a week, but as it takes only two or three minutes they do not regard it as any trouble.

Such is the evidence which we have received on the practical side of the disposal of sewage in rural districts. Dr. Poore's evidence is of so special a character that I have thought it desirable to treat it separately. For many years he carried out experimentally a system of disposal of fæcal matter from the inhabitants of eighteen cottages of which he was the landlord; the results are embodied in two books, which have had a large circulation, named "Rural Hygiene" (Longmans, 1894); and "The Dwelling House" (1898).

The two principles for which Dr. Poore contended are (1) that putrescible refuse should not, where it can be avoided, be mixed with water, and (2) that all putrescible refuse, whether mixed with water or not, should be dealt with on the surface of the ground, *i.e.*, in the upper layers of cultivated soil. This has been the successful practice of agriculturists in all ages and climates. The fæcal matter is collected in pails daily by an elderly man; he goes round the closets with two buckets with lids, into which he empties the contents of the eighteen to twenty-three pails of his cottages. He disposes of the fæces in shallow parallel furrows less than one "spit" (the length of a spade—9 inches) deep, and covers it in with earth, the ground having then the appearance of a carefully prepared garden bed. At the earliest opportunity cabbages are dibbled into this bed; when these have matured the second crop may be anything suited to the soil and situation. The second crop is very valuable and the necessary tillage ensures the complete humification of the fæcal matter. There is an obvious advantage in having this land as near the house as possible, for it creates not the slightest nuisance, and it is covered with very luxuriant vegetation. Dr. Poore suggests that in addition to his wages, the attendant, whose duty it is to empty the receptacles, should have a bonus of 10 per cent. on the sale of the produce of the gardens; the disposal of the fæcal matter of about 100 persons takes him from twenty minutes to half an hour a day. To receive that from 1,000 persons, half an acre would be ample,* and the garden should prove very remunerative; even with his own small garden of 1 acre, 1 rood and 7 perches, the fruit was sold for £78, £82, and £91, during the three preceding years, leaving a handsome profit after paying his gardener's wages. I am myself disposing in my garden of the fæcal matter from a school of 250 children, and can in every respect confirm Dr. Poore's experience. It would appear as if this comparatively large quantity can be satisfactorily disposed of on a space of about 1,500 square yards per year; and the trouble and time required are insignificant.

The buckets used for carrying the night soil should be dusted with soil or ash after use. No washing or white-washing is advisable, and no disinfecting chemicals should ever be used, for antiseptics hinder nitrification in the soil. Dr. Poore's experiments lasted for more than eighteen years, so that their value has been thoroughly proved. There is no doubt that under efficient supervision his plan is as good as can be devised.

As Dr. Poore says:

> "In the decent, wholesome and profitable disposal of excrement there is no difficulty. The only things needed are the will to do it, a bit of land and a set of garden tools."

But the question as to the disposal of slop-water arises; where there is a public water supply under pressure the amount of water to be disposed of, owing to baths, etc., may be very considerable. Dr. Poore points out that domestic slop-water is not foul smelling until putrefaction sets in, and putrefaction should not be allowed to occur. His plan of getting rid of slop-water is to have all waste pipes of sinks, etc., terminate at least 2 feet 6 inches above the level of the ground; the sinks should not be trapped, and between the waste pipe and the ground there should be interposed a strainer and a coarse filter. The strainer is a basket with a wisp of straw in it which requires to be changed, say, once a week or once a fortnight; the contents may be given to the fowls or pigs or put on the manure heap. The filter may consist of an old bucket (a disused bucket), the bottom of which is perforated, filled with coke or clinker varying in size from peas or marbles at the bottom to French walnuts at the top. The effluent from the filter should run into a "filtration gutter," consisting of a perforated gutter of cast-iron, 9 inches wide, with horizontal flanges, accurately adjusted with a very gentle slope by placing loose bricks at the junctions of the lengths of guttering, which are each six feet. Rubble is packed in the trench beneath the gutter. The length of the gutter need not exceed 8 or 10 feet, and it costs 1s. 6d. per foot. The sides of the gutter should be planted with some plant which likes moisture, such as black-currant or raspberry. It is important to have an open and not a closed gutter, for air and light should have free access to the slop-water. It is often an advantage to take waste waters in different directions, for it is obvious that by lessening the quantity of fluid taken to any one spot we lessen the risk of saturating the soil. Even in country houses where water-closets are insisted on, Dr. Poore thinks it would be a good plan to treat night soil separately and to allow slop-waters and urine to flow in open gutters.

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* Poore's "The Earth," Longman's, 1902, p. 195.

Dr. Poore, in order to demonstrate that the effluent from garden soil thus treated with fæcal matter is perfectly sanitary water, constructed a well, 5½ feet deep, in the middle of his garden. The sides of the well are lined with concrete pipes to the very bottom, and around these 4 inches of concrete have been run in to give additional protection; there is a parapet and cover; the bottom is covered with sand. The water is bright, colourless, odourless and tasteless, singularly free from bacterial contamination, although the nitrogen content, as might be expected, is high. The water was examined bacteriologically in 1891, and again in 1902, and was found unexceptionable. He drank this water occasionally for ten years and suffered no harm. The depth of water in the well is only 3½ feet, and its diameter 2¼ feet.

The well stands in a little circular plot of about 20 feet diameter; the trenching occasionally goes close to this plot, but 8 or 10 feet of soil filtration suffices to purify any product from the soil, and render it perfectly wholesome to drink.

In cold damp weather the nitrification of the fæces goes on very slowly, but Dr. Poore has frequently observed that each lump of fæcal matter gets covered with a crust of soil which prevents its disintegration and washing down into the soil during wet weather; this state of things persists during most of the winter; frost breaks up and disintegrates these lumps, so that in spring they are completely humified. In summer, or in mild weather, humification begins at once, and the land may be at once planted with cabbages, dibbled in.

Dr. Poore, in explaining in cross-examination why the system which he has advocated for years has not been widely adopted, stated that

> "The law is against one; where two or three cottages happen to drain into one pipe, that pipe becomes a sewer maintainable by the Council of the district. I find that fact alone is too much for me. . . . I think it is a pity that the sanitary well-doer cannot be, so to say, encouraged."

Professor Harley's evidence went in the direction of confirming Dr. Poore's as regards the insistence of changes being made in the drainage arrangements of his tenants, changes which he knew to be insanitary. For instance, a cess-pit was insisted on, the effect of which was to store drainage water and render it foul instead of allowing it to run off in open gutters and be oxidised.

The opinion to be drawn from the evidence which has been summarised is that where houses are so situated as to have gardens of their own, or sufficiently near a piece of land which can be used as a garden, of one-eighth of an acre, or even less, there is no difficulty in disposing of night-soil, not only satisfactorily, but profitably, always provided the small amount of trouble is regularly undertaken. Where each house has a garden, even if it be a small one, there is also no difficulty in disposing of slop-water, even if the house be supplied with water by a Water Company. I have myself proved its practicability, even on a stiff clay soil. Difficulty arises, however, where there is mixed population in a village or small town, some of the houses possessing gardens, while some are built in terraces. Dr. Parsons, in his evidence, says:

> "It seems to me that people object more and more to do anything that involves individual labour and responsibility, and they wish to throw more and more on the Public Authority. I have heard that difficulties

have arisen on that score in the Garden City. People go there, who have been accustomed to live in towns where the refuse has been collected by the Public Authority, and they object to the labour and trouble of disposing of it themselves on their own gardens. They expect it to be removed as they are used to in the towns."

When asked for a suggestion to solve this difficulty, his reply was:

"In the case of a compact village with a large rural area within the contributory place a small scheme might be allowed for the village alone, and that the law should give the means of charging the cost of this upon the area that is benefited by it. But in the present state of the law it can only be carried out at the cost of the whole contributory place, and that causes a great deal of opposition, so the works are not carried out; or, on the other hand, it may be contended that if everyone in the parish has to pay, everyone in the parish ought to have the benefit, and so larger works are proposed and carried out at, of course, a much greater expense than is needed. . . . If the houses are close together, the cost will be comparatively small; if the houses are a long way from one another, it means a long length of pipe to connect them together. . . . In a village where there are no sewers, or no public water supply, a man may buy a small plot of land and erect a row of cottages on it without more open space about them than is required under the by-laws for securing a circulation of air. There is no power to require him to provide an additional amount of land in order to dispose of his refuse on it."

"You think that power should be given?" "I think that power should be given."

Dr. Parsons goes on to say that he would give the local Authority power to forbid the connection of house drains conveying foul liquid to highway drains; and also to forbid the construction of water closets in places unless means were provided for the innocuous disposal of the sewage.

The question of the prevalence of flies has been alluded to, as an objection to all schemes of sewage disposal except water-carriage. Dr. Handford was inclined to attribute to pail-closets, and the flies which infest them, outbreaks of enteric fever; but he inclined to think that the flies frequented the "tips" where pail closets are emptied, where their emptying is carried out by scavengers in the larger communities.

Dr. Poore considers this question from the medical point of view in his book on "The Earth," pp. 196, 197. He there says:

"The fly is a robber which has been bred in material which we have deliberately allowed to lie above ground, instead of covering it up with soil."

Flies do not settle on fresh excreta; and the fæces should always be buried while fresh.

To a scientific man the waste of nitrogen, which goes on at present, is appalling; the world's supply is being rapidly exhausted; it is estimated to last, at the most, barely fifty years. It is true that of recent years atmospheric nitrogen is being combined so as to yield substances of manurial value, but even though such chemical compounds may compete with natural "caliche" (or nitrate of soda from Peru), it is no less true that in their manufacture power is being consumed which could be profitably employed in some better manner. It may also be taken for granted that the recovery of the nitrogen from water-borne sewage can never pay, except, perhaps, in some specially favourably situated localities. It may be contended that during the conversion of the contents of domestic manure into nitrates, available for plant food, there is a loss of nitrogen, evolved as such, and that nitrogenous matter will also be washed into the soil, too deep for the roots of plants to reach. It may be replied that such a loss is certainly more likely to occur with salts of ammonium, or nitrates, which are much more soluble than are the constituents of natural manure. Moreover, natural manure decomposes slowly, and supplies plants with a constant small quantity of nitrogen, which may be, in the aggregate, larger than that spread on the fields as nitrates. These considerations lead me to believe that, wherever it is possible, the nitrogenous matter consumed as food should be returned to the soil. We have learned from the evidence cited that this can be easily, and from Dr. Poore's evidence, profitably done, without any serious expenditure of time or money, but that the difficulties in the way of earth disposal in the case of rural communities consist: (1) in certain obstacles placed in the way of such attempts by legislation, (2) in the ignorance of the populace, and (3) in the increasing tendency to thrust all responsibility on other shoulders—the Public Authority. We have been told by Dr. Handford that no attempt is made in school to teach that part of domestic economy necessary for sanitation; that the teachers consider it, in his opinion, *infra dig.* He himself regards it as a necessary part of human life and believes that it should form a subject of instruction in all schools.

Two objections have been raised to the conclusions to be drawn from this Memorandum: First, that if there is a public water-supply, it is difficult, if not impossible, to dispose of bath and slop-water. Second, that while the rural disposal of refuse is admirable in skilled hands, it is hopeless to expect it to be always carried out without a nuisance. To the first of these objections, I may reply that both Dr. Poore and the writer have had no difficulty in disposing of wash-water in the way the former suggests; and second, that the intelligence of the population must be regarded as most rudimentary and almost incapable of improvement, if the very simple plan of disposal laid down by Dr. Poore is pronounced beyond the power of an ordinary small householder. From my own experience, I can vouch that the trouble is very slight; that there is absolutely no nuisance; and that the householder has the satisfaction of seeing his garden increase in fertility to an extent which he would not at first imagine. As soon as he sees that he is saving money, and that his garden increases in productivity, he will gladly face the small amount of trouble involved. The first thing is to convince him that *shallow* burial of excremental matter is necessary; as a rule, the matter is disposed of in pits, where it remains as a filthy mass. This involves instruction by precept and example.

I therefore recommend:

(1) That legislation be so framed that no obstacle shall be placed in the way of any person or community, preventing them from disposing of sewage and slop-water in the soil; and that where there is a mixed community, part of which lives in terraces and streets, and part in isolated houses, rates for a water-carriage scheme should be levied only on those houses which are served by it.

(2) That Inspectors be encouraged to gain knowledge as to the elementary principles involved in the domestic disposal of sewage by the issue to them and to the public of literature dealing with accredited means of disposal.

(3) That a simple set of regulations should be drawn up for use by the public, the contravention of which should be punishable by a small fine; and

(4) That booklets of instructions should be issued at a cheap rate, so that no householder can remain in ignorance of means which will easily dispose of his refuse, while at the same time his garden will be rendered much more productive.

I would urge strongly that steps should be taken without delay to improve the methods of sewage disposal among rural populations as suggested in this Memorandum, knowing that the social and sanitary conditions of so many of the inhabitants of this country will be affected by this action.

MEMORANDUM BY SIR WILLIAM POWER, K.C.B., F.R.S.

Participation during many years in the work of the Commission, particularly in that of its expert investigatory staff, has greatly impressed me with a sense of the important issues involved in its "findings." So far as the scientific aspects of the problem committed to the Commission are concerned, the marshalling of fact and the statement of inference adopted by my colleagues has my concurrence. Also I am in agreement with them as to directions in which the law governing Rivers-Pollution administration needs to be altered. But I regret that the promise, held out in paragraph 24 of our Ninth Report, of indication by the Commission "in greater detail of what should be the functions of these bodies (Rivers Boards) in relation to the discharge of manufacturing wastes directly into streams" has not been more adequately fulfilled. Hence this separate Memorandum.

To me it has appeared of essential importance that Watershed Authorities should definitely be charged with control of Volume as well as of Quality of water in their rivers; and that the Commission, while summing up the powers, duties and functions proper to be conferred on a Watershed Authority, should utilise fully the experience gained of the problems with which such Authority will in practice be confronted, and go on to indicate, in due proportion and orderly sequence, the procedures adoptable by the Watershed Authority in exercise of such powers, duties and functions,—and this not least as regards sections of river that are neither drawn on for public water supply nor are tidal. In a series, therefore, of memoranda in which I sought from my colleagues acceptance of propositions in this sense, I set out a number of considerations in support of them. These memoranda may prove of service to the Department of Government called upon to deal with questions, legislative and administrative, arising as a result of the pronouncements of the Commission.

The review which seemed to me called for of the theory and practice of administration by the Watershed Authority, was necessarily practicable only on termination of the important concluding sections of the Commission's investigations, those as to trade wastes; and, unfortunately, the stage at which it became practicable, and at which I had come to regard myself as under obligation to press the considerations referred to on my colleagues, coincided with strong extraneous pressure specially brought to bear on the Commission to bring its long sustained labours to a close. In the circumstances the time remaining at our disposal did not suffice me for gaining adherence of my colleagues to my view.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

NINTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(Including any Liquid from any Factory or Manufacturing Process)

MAY PROPERLY BE ADOPTED.

I. DISPOSAL OF LIQUID WASTES FROM MANUFACTURING PROCESSES.

II. DISPOSAL OF LIQUID AND SOLID DOMESTIC REFUSE IN RURAL AREAS.

VOL. II.—EVIDENCE AND APPENDICES

(Including Memoranda giving the results of Experiments on the Treatment of Specific Trade Wastes, by Officers of the Commission, and Experiments on the Manurial Value of Sewage Sludges, by Dr. J. A. Voelcker and by Dr. E. J. Russell and Mr. E. H. Richards).

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE,
By WYMAN and SONS, Limited, 109, Fetter Lane, E.C.

To be purchased, either directly or through any Bookseller, from
WYMAN and SONS, Limited, 29, Breams Buildings, Fetter Lane, E.C., and
28, Abingdon Street, S.W., and 54, St. Mary Street, Cardiff; or
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T. FISHER UNWIN, London, W.C.

1915.

[Cd. 7820.]

Price 1*s*. 4*d*.

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MINUTES OF EVIDENCE

TAKEN BEFORE THE

ROYAL COMMISSION

APPOINTED TO

Inquire and Report: First, what method or methods of treating and disposing of Sewage (including any Liquid from any Factory or Manufacturing Process) may properly be adopted consistently with due regard for the requirements of the existing Law, for the protection of Public Health, and for the economical and efficient discharge of the duties of Local Authorities; and if more than one method may be so adopted, by what rules, in relation to the nature or volume of Sewage, or the Population to be served, or other varying circumstances or requirements, should the particular Method of Treatment and Disposal to be adopted, be determined; and, secondly, to make any Recommendations which may be deemed desirable with reference to the Treatment and Disposal of Sewage.

ONE HUNDREDTH DAY.

Tuesday, 13th June, 1911.

PRESENT:

Colonel T. W. **Harding**, J.P., D.L. (*in the Chair*).
Sir **William Ramsay**, K.C.B., F.R.S.
Sir **William H. Power**, K.C.B., F.R.S.
Mr. F. J. **Willis**.
Mr. R. H. H. **Keenlyside** (*Secretary*).

ALSO PRESENT:

Dr. **George McGowan**.
Mr. C. C. **Frye**.
Mr. G. B. **Kershaw**.

Dr. **John** C. **M'Vail**, Medical Officer of Health for the Counties of Stirling and Dumbarton, called in, and Examined.

Dr. John C. M'Vail.
13 June, 1911.

31912. (*Chairman.*) You are, I think, Medical Officer of Health for the Counties of Stirling and Dumbarton?—Yes.

31913. And you have prepared for us a statement which we have read with much interest. It deals mostly with the administrative difficulties that lie in your way in this part of Scotland?—That is so. (*The following Statement was handed in.*)

1. *Administrative Areas.*—In respect of the failure or success of any department of Local Government a fact of essential importance is the extent of the administrative area. Different purposes may require different areas. Twenty years' experience has shown that the Local Government (Scotland) Act of 1889 made a most valuable reform in altering the public health unit of administration from the parish to the county district. The vested interests in any particular nuisance was much greater and more influential in the small area than in the county district where the great majority of the members would be under no local influence for the protection of any individual offender.

In framing the Rivers Pollution Prevention Act of 1876, the possible influence of river pollution on health may perhaps have been the consideration which led to the local sanitary authorities being selected as public bodies empowered to enforce the Act. Under the Local Government (Scotland) Act of 1889, County Councils were similarly empowered so that the Act may now be enforced, either by County Councils or District Committees or by Town Councils.

In addition, the 1889 Act, Sec. 55 (3), provides that if any County Council or Town Council applies to the Secretary for Scotland, he may by Provisional Order give power to administer the Act to a Committee representative of all the Counties and burghs through or by which a river passes. I am not aware that this provision has ever been taken advantage of in Scotland, but it indicates that by 1889 Government had come to recognise the principle according to which the boundaries of an administrative area for the purpose of rivers pollution prevention should be determined. The fact that Sec. 8 of the Act of 1876 enabled a sanitary authority under restrictions to take proceedings in respect of offences against the Act, even if committed outside their own boundaries indicated that even then there was some inkling of the proper lines of administration in respect of area.

It is quite clear that a public health area is not necessarily co-terminous with a rivers pollution area. On the contrary, within my personal knowledge, the County of Lanark is the only County Council area which makes any approach to being suitable for the administration of the Rivers Pollution Prevention Acts. Strictly speaking, that County itself is not a public health area, but contains three county districts and many burghs, each separately responsible for public health functions. But the provision in Sec. 55 (1) of the Local Government (Scotland) Act, 1889, empowering a County Council to administer the Act, has permitted the non-tidal part of the Clyde and most of its tributaries to be taken charge of by the County Council. The ancient name of Lanarkshire was Clydesdale

6225. 1500.—Wt. 9302. 3/15. Wy. & S. 3562*r*.

and the map shows that its boundaries consist largely of the watershed of the River Clyde. It appears to me that that is exactly the principle which should be followed. For each river or large tributary, the administrative area should be the whole country contained within the watershed.

The facts, however, with regard to existing boundaries of counties and county districts are very frequently just the opposite. The river and not the watershed is the boundary. Stirlingshire on the north is separated from Perthshire by the River Forth. The Kelvin, a principal tributary of the Clyde, separates Stirlingshire on the south from the detached part of Dumbartonshire. Still further south the detached part of Dumbartonshire is separated from Lanarkshire by the Luggie, a tributary of the Kelvin. In the east, the River Avon separates Stirlingshire from Linlithgowshire, and in the west the tidal part of the Clyde separates part of Dumbartonshire from Renfrewshire. The Endrick, before it enters Loch Lomond, separates Dumbartonshire from Stirlingshire. The result is that none of these rivers are under the control of any single Public Health Authority, and it is quite impracticable for any authority which has an interest in any part of one of them to attempt to administer the whole. To do so would give rise to constant friction and dispute with other local authorities and would involve the authority making the attempt in expenditure for inspectorial work, chemical analyses and so forth, quite outside its own area.

The particular case which has most impressed itself on my own notice as illustrating the above difficulties is that of the River Kelvin and its tributaries. There are included within its watershed the burghs of Kilsyth, Kirkintilloch, Milngavie, parts of Glasgow, and Partick, and the county districts of Central Stirlingshire, Western Stirlingshire, Eastern Dumbartonshire, and the Middle and Lower Wards of Lanarkshire—a total of ten separate Public Health Authorities. Quite recently, in connection with pollution of the Luggie, inspections were separately made on behalf of Dumbartonshire, Lanarkshire, and the burgh of Kirkintilloch, and the reports were in some degree conflicting. Then it became necessary that all the three inspectors along with an analyst should make a joint visitation of the whole of the Luggie and try to agree on a joint report. Much official time was thus wasted, and much delay took place in determining the offenders.

In the formation of Rivers Conservancy Boards one or two points have occurred to me, as requiring attention. The area of burghs is much smaller than that of county districts. A burgh therefore is almost certain to be wholly within one watershed, whilst the county district may embrace parts of several watersheds. In fixing the number of representatives of each authority on any Board and in allocating the cost, while whole burghs would as a rule be included, only the parts of the county districts within the watershed should be represented or rated.

Another point is that, if practicable, the area should be such that no single partner in the combination should be predominant over all the other partners combined. It may however be difficult always to give effect to this. On the Clyde, Glasgow is paramount and naturally its representatives would have Glasgow interests specially in view. Wherever the Board might have any such predominant partner there should be some central authority as a court of appeal. No doubt such a court of appeal would be desirable even in the absence of a predominant partner. If a Conservancy Board were proposed for the Clyde and its tributaries, the actual area embraced would depend on whether or to what extent the tidal waters of the Forth were to be included. Under the Rivers Pollution Prevention Act no tidal water is included unless (in Scotland) by Order of the Secretary for Scotland. If that principle were adhered to and one Conservancy Board were formed for each river then the Kelvin which discharges into the tidal part of the Clyde would have a Board of its own. So also would the White Cart which passes through Paisley, and the Leven in Dumbartonshire. But if tidal waters were included even to the Cloch Lighthouse where the Firth turns southward such streams as the above would be included. I presume Ayrshire, however, would not be embraced in the Clyde area though it borders on the Firth, nearer the open sea.

Officials.—At present inspection is commonly done by the sanitary inspectors under instruction by the Medical Officer of Health who sometimes also takes part in the work. Very few Public Health Authorities appoint special inspectors, the areas being seldom large enough for whole-time officers. If the areas were fixed according to the watersheds and without relation to the Public Health Districts a staff of inspectors, quite apart from those engaged in public health work would probably have to be appointed, and naturally the desirability of having an administrative area sufficiently large to employ a whole-time staff would be kept in view, other things being equal.

Tidal Rivers.—The situation of the counties of Stirling and Dumbarton between the Firth of Forth on the east and the Firth of Clyde on the west has raised various questions relating to tidal waters.

Gareloch.—The Gareloch is an arm of the sea very much enclosed by land. Its pollution was the subject of a report in 1895, of which a copy is submitted herewith. Following on the report, application was made to the Secretary for Scotland to declare the Loch a " stream " under the Rivers Pollution Act. This application was never either formally granted or formally refused and the County Council did not press for a verdict. Their difficulty was that if the Loch had been brought under the provisions of the Act they would have been faced with the duty of preventing discharge into it of any untreated sewage. To compel separate treatment of the sewage from every house, small and large, along the side of the Loch would have involved very great expenditure and would in fact have been impracticable. The formation of each of the more populous places into a Special Drainage District so as to have common treatment of village sewage would also have presented almost insuperable difficulties. At the village of Garelochhead for example, with a population of about 600, the houses are arranged right round the head of the loch, many of them very little above high water mark. It would have been impossible to lead all the drainage to one common point for treatment owing to want of fall. Also, the amount of rock-cutting would have been prohibitive. In these circumstances the County Council proceeded no further in the matter, but the condition of the Loch has been much improved by the formation of Row into a Special Scavenging District, with frequent refuse removal and attention to the foreshore, and by voluntary agreements for scavenging of other populous places. Also, on the training ship "Empress," with a population of several hundred boys, care is now taken to discharge sewage only on the ebb tide.

Carron.—The tidal part of the River Carron, which falls into the Firth of Forth has presented special difficulties. The tide flows up to Carron Iron Works which are at a distance of about four miles from the Firth of Forth as the crow flies but very much greater along the river owing to its quite exceptionally winding course. The entirely untreated sewage of the Burgh of Falkirk is discharged into the tidal part of the Carron. The sewage of Larbert, Stenhousemuir, Carron, and Carronshore, all within the Eastern District of the County and under the charge of the District Committee, is also discharged into the Carron at a point higher up the stream than where Falkirk sewage enters. The county district sewage is however treated by settling ponds, and a large quantity of solid matter in suspension is in this way removed from it. Between the treatment works for Larbert and Stenhousemuir, and the point of entrance of Falkirk sewage, there is situated the village of Carronshore. The banks of the river consist of a dark thick mud, covered at high water and exposed at low water. The numerous bends in the course of the stream cause deposit of large quantities of Falkirk excrement on the mud banks, and there is frequent complaint of nuisance by the inhabitants of Carronshore. Whether the condition could be proved injurious or dangerous to health is a question which could only be answered in a law court, but undoubtedly the amenity of the district is seriously interfered with. The circumstances place the County Council and District Committee in a serious difficulty. They do not wish to take legal proceedings against the Burgh of Falkirk who have taken no action to improve matters and they hesitate to ask the Secretary for Scotland to declare the tidal part of the river a stream in the sense of the Act lest the rigid application of the Act should involve waste of money both by Falkirk and by their own ratepayers in achieving a needless degree of purity. In their opinion the case would be met by prevention of entrance of suspended matter from Falkirk sewage into the river, but the Act does not contemplate any such limitation of purification methods. It seems to me that in any future legislation on the subject the case of tidal rivers should be dealt with. They should to some extent be brought under the Act, but the standard of purification should be decidedly lower than in the case of non-tidal rivers. So far as the Carron is concerned reasonable means for removal of suspended matter should suffice.

Leven.—The case of this river illustrates some of the difficulties that local authorities meet under the existing Act. The Leven is about 7½ miles long and carries the waters of Loch Lomond into the Clyde at the town of Dumbarton. The highest point affected by spring tides is 3 miles above the entrance of the river into the Firth of Clyde. It is a large stream with a good flow. Along its banks there are situated large industrial works for turkey-red dying and calico printing. These trades have been established on the Leven for considerably more than a century. Also, independently of the town of Dumbarton which is on the tidal part near the mouth of the river, there is a population of about 20,000 in the Vale of Leven and Renton where the river is non-tidal. This population is entirely under the government of the District Committee of the County Council. The question of a complete scheme of purification of the Leven has from time to time been under discussion since County Council Government began in 1889, and even before that date. In 1897 a meeting was held of representatives of the authorities and manufacturers, and a full enquiry was agreed on, the expense being borne jointly by those concerned. Reports were obtained from the late Sir W. R. Copland, C.E., and from Mr. Tatlock, chemical analyst. Briefly, the scheme was to carry all the sewage effluents and the manufacturing effluents to common settling ponds at the south end of Renton, with a view to precipitation by mixture of the works effluents with the sewage. The cost of the scheme and of its maintenance and management would have required a rate of 2s. 2d. per £ levied jointly on owners and occupiers—including the works—within the localities concerned. In considering whether this very heavy expenditure would be justifiable on public grounds, note has to be taken of facts like the following :—The river is not used for drinking purposes nor for the watering of cattle. It flows at a fairly rapid rate between well-defined banks, and wherever necessary the sewers are carried right into the running stream so that there is no exposure of putrefying organic matter on the shingle at the sides of the river. There is not the slightest evidence of danger or injury to health. The only objections are some discolouration of the water by the dyeing materials, especially by turkey-red, and possible injury to fish life, affecting the fishing in Loch Lomond. The Leven discharges into the waters of the Firth of Clyde just where it begins to widen. On a £10 rental in the Vale of Leven the rate at 2s. 2d. per £ amounts to 21s. 8d. per annum, one half payable by the owners and the other by the occupiers. I have no hesitation in expressing my own opinion that an artisan or labourer living in such a house would get much better value for his money by spending it on household necessities than by paying any such rate for purification of the Leven. Also, I am of opinion that the interests of Loch Lomond fishing, while not negligible, are not nearly worth the outlay indicated. The engineer's report was obtained in 1899. It is alleged on the one hand that prices for the work involved are much higher now than formerly. On the other hand it has been suggested that a much smaller scheme would suffice and that a relatively small part of the effluent from the works would require treatment and could be kept apart from the rest. In the meantime, the policy of the County Council has been to bring pressure on the turkey-red and calico printing works to purify their discharges. As regards sewage an installation for biological treatment has been provided for a new population connected with a recently introduced industry, the Argyll Motor Works, but for the rest of the poplution practically nothing has been done. Without pumping, filtration would be impracticable and the cost of construction of septic tanks would be very great. Much of the housing is on a level little above that of the river, and many sewers are laid down to the river at quite a number of separate points. The possibility of constructing septic tanks at the end of each sewer and below the level of the river might be considered, but adjoining a running stream such tanks would have to be very strongly built in order to be water-tight, and after all, they would act only as cesspools and would give anything but a pure effluent. The town is an old one and was built when there was no thought of rivers pollution or purification. I have brought the facts before the Commission simply to illustrate the difficulties that exist in administration of the Acts and to show the necessity for comparing with the cost of purification the actual value of the results which would be achieved.

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Coal Dross Pollution.—Coal-mining is an important industry in Central and Eastern Stirlingshire. and in the detached part of Dumbartonshire. Consequently, especially since coal washing became so common, pollution by coal dross has been of frequent occurrence. The methods of dealing with it are well known and under action by the County Councils there has been very great improvement, enormous quantities of coal refuse being now retained which would otherwise have found their way into the streams. The main source of pollution is of course, coal washing, but very serious contamination sometimes occurs when floods wash refuse from the waste bings of collieries and also from the whole area around the pit head where the surface of the ground consists largely of broken down coal. Pollution from this source ought to be the subject of special regulation, but in the case of old collieries where refuse heaps have been accumulated for many years new lessees of the works find themselves in a very difficult position. The coal owners who accumulated the refuse have nothing to do with the works and the present owners did not contemplate any such responsibilities when they took them over.

A point as to which personally I am not quite clear but which probably presents no real difficulties is as to water pumped from coal mines. Such water often contains coal dross in suspension. Does the Act apply to this pollution ? Sec. 5 applies *inter alia* to persons who cause any solid matter from any mine to *flow* into a stream, but Sec. 20 says that "solid matter shall not include particles of matter in suspension in water." I have never understood how solid matter could flow into a stream unless it were in suspension. If the Commission think it worth while this point might be cleared up in their report.

Sampling.—Probably every question under this heading has already been before the Commission. I have on various occasions discovered that polluting effluents were being very considerably diluted by runlets of water or small streamlets before discharge into a river, and that in this way analysis of the effluent was apt to give a fallacious result. Even in trade processes the quantity of water used may greatly vary according to the abundance of water supply available. The actual quantity of polluting matter should be ascertainable and not merely its state of dilution or concentration. Also, in every work, there should be places convenient for taking samples. It is quite common to have an outfall pipe led far out under the surface of a river into mid stream or sometimes into a covered 'lade' which brings the water from the river at one point and returns it to the stream at a lower point. Inspectors under the Act should have right of access at any reasonable time and without previous intimation.

Establishment of New Manufactories.—When a manufactory of a nature likely to cause rivers pollution is about to be established within the area of a Rivers Board, it would be convenient if the responsible public authority had notice of the intention. In Stirlingshire, one important work for the manipulation of bye-products connected with the coal-mining industry has been begun and greatly extended within the last few years. Its effluents include a considerable quantity of phenols though these are diluted by water pumped from an adjoining mine. There is no available waste heat for evaporating the phenol effluent and I am told that phenols are particularly difficult to dispose of by means other than evaporation. At the work in question a very serious effort is being made, under the guidance of Dr. Gilbert Fowler, to deal with the effluent by biological methods but at present there is only an experimental installation, treating about 9,000 gallons daily or about one-hundredth of the total discharge. What the result may be is still uncertain but a conference with the rivers authority previous to the erection of the works might have been a great advantage.

Flooding of Adjoining Lands.—Much of the valley of the river Kelvin is very low lying land and very little above the ordinary level of the river, being in some places guarded by embankments. Few years pass without large tracts of the adjoining country and of the public roads being flooded for days at a time. It is urged on some hands that this could be partly obviated by clearing the outfall, by removing

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silt which has accumulated in the bed of the river, and by removing also a weir, no doubt originally erected in connection with the water supply of a flour mill or other local industry. Various abortive discussions have taken place on the subject, but at present, as already pointed out, the Kelvin and its tributaries are within the districts of no less than ten local authorites and nothing effective has been done. It is even doubtful whether, if willing, the local authorities could use their funds for clearing the outfall. There is also the question of whether the owners of flooded lands who would be benefited should not contribute to the cost of any such improvement. It seems to me that the subject is worth the consideration of the Royal Commission with a view to legislation.

31914. And you have pointed out, among other things, what an advantage it would be if there were Watershed Boards as a centre of administration for rivers pollution ?—Yes.

31915. Together with a Central Authority in London which could be appealed to in case of difficulties arising between such Boards and Local Authorities or private persons ?—Yes.

31916. May I ask first whether you are familiar with the recommendations which have been made by this Commission in regard to these matters ?—Yes, I have read the evidence as it appeared.

31917. Have you read the Reports ?—Yes, I have read the Reports generally.

31918. And I suppose I may take it that substantially what you think is advisable is precisely what this Commission has already recommended ?—That is so with regard to Boards. I do not think any case can be more striking than that of Stirling and Dumbarton. On that point, I have got a map with me. The whole of the two Counties are separated by rivers receiving pollution on each side. On the North there is the River Forth separating Stirlingshire from Perthshire. And then, on the East, the River Avon separates Stirlingshire from Linlithgowshire. On the South there is a detached part of the County of Dumbarton; it is the only detached part of any county remaining in Scotland. The Kelvin separates Stirlingshire from the detached part of Dumbartonshire on the North, and then that detached part itself is separated from Lanarkshire by the Luggie. Then, along here towards the West, the Endrick separates Stirlingshire from Dumbartonshire, and the tidal part of the Clyde separates Renfrewshire from Dumbartonshire, so that we have nothing like a watershed. Our boundaries, from end to end, are wholly rivers; and then the two Counties lie between the Firth of Forth on the East and Firth of Clyde on the West, both of which reach far inland, and the streams entering them are to a considerable extent tidal, so we have far inland portions of rivers that are not under the Rivers Pollution Act at all, but are tidal streams. The Counties are situated just in the centre of Scotland between the two Firths and all these questions arise in an exceptional degree.

31919. So that you really point out to us that the bodies to whom is entrusted the administration of these matters are separated by the streams themselves, and find a great difficulty in working together ?—Yes, the Kelvin has ten different Sanitary Authorities interested in it. It is a comparatively small river; it is only a tributary of the Clyde, entering the Clyde where that river is tidal, and on that River Kelvin and its branches there are ten Sanitary Authorities.

31920. Then, your strong view is that Boards are necessary to deal with these matters ?—Absolutely necessary, and they should be large enough to eliminate local influences. There is nothing of more consequence in local government than the size and the area of administration, no matter what the department of local government is. It may be a question of ordinary nuisance under the Public Health Act. A village for example is too small; you want a county district, where you are independent of local influence. On the other hand, if you come to the pollution of a river, which is a considerably larger question, you require a correspondingly larger area of representation, in order to get independent action.

31921. It would be interesting in connection with that to know whether you would say, for instance, a Watershed Board for the Kelvin would be necessary, or whether that could be absorbed into the larger watershed of the Clyde itself ?—Well, that is a very difficult question. I have thought of that often. The one particular difficulty with regard to including it in the Clyde would be this; that in any event Glasgow would be the paramount partner; it would be overwhelmingly greater than all the others put together. Now, that is not an ideal Board; a Board where one partner has more say and more interest than all the others combined; because naturally and inevitably the particular requirements of that one partner are apt to over-ride the requirements of the other districts. If you have that, you would certainly require a very strong Central Body for appeal, and such a Central Body having control of such a Local Board should not merely hear of the doings of that Local Board when a case of appeal occurs. They should have regularly before them the proceedings of that Local Board, and should take an interest in those proceedings, so that without any need for a representation by any one of the smaller authorities on the Local Board, the general management by the Board could come before the Central Authority without appeal.

31922. We are very much interested to hear your views. They are substantially already embodied in the paper you have put before us, and, therefore, I will not take up your time nor that of the Commission by going into them in further detail, seeing that we have this paper before us which can be embodied in our evidence. Now, you say something in the latter part of this paper in regard to tidal waters, and the amount of purification that you think might be necessary in such a case. You point out that it would be undesirable to put Local Authorities to very serious expense for a complete purification of their sewage, or of their trade effluents, if simple sedimentation or precipitation would suffice—That is so. One hesitates to ask that a tidal stream shall be included under the Rivers Pollution Act, because immediately it is so included you at once get into the position that the requirements for purification for the tidal stream must be the same as those for the rest of the river, and it comes directly under the provisions of the Rivers Pollution Act with regard to the discharge of sewage into it. Now, that would be a great hardship, as I have pointed out, in the case of the Gareloch, it is an arm of the sea; it is not to any appreciable extent the widening of a river; only a small stream enters at the head of it. It is really an arm coming in from the sea, rather than a river expanding as it reaches the sea. Then, there was a good deal of pollution there, and we did appeal to the Secretary for Scotland to declare the Gareloch a stream under the Rivers Pollution Act. We never got any definite reply. I was told at the time that the Law Officers of the Crown had been consulted, and on account of the fact that it was not an expansion of a river, but only an invasion of the sea, some of the Officers hardly thought it was a case for bringing under the Rivers Pollution Act.

31923. What would have been the effect of bringing it under the Rivers Pollution Act ?—It would have been this; that villages along the shore would have been put into the greatest possible difficulty as regards the purification of their sewage. Their houses are situated on rock at the same level right round the head of the Gareloch, the village of Garelochhead, and so on. There is no common point of fall to which the houses could have been drained for the purpose of sewage treatment. Each house almost would have required to purify its own sewage. What we have done there is to establish a scavenging district at the place that was giving us most concern. Under the Scottish Public Health Act, what are called Special Districts may be formed. That is a very useful power for the provision of certain public services—drainage, water, scavenging or lighting. A special district is carved out of a county district, and within that special district a particular service is given, and is paid for by assessment of those within the district. Well, we formed a scavenging district for Garelochhead, and did a good deal there towards cleaning the foreshores. For other populous places along the Gareloch, arrangements were locally made in substitution for a scavenging district by voluntary contribution, and in that way the foreshore was considerably cleaned. We also got many of the drains carried out to low water mark, and we got the " Empress " to discharge the latrines there only on the ebb tide.

31924. Then, have you formed the opinion that it is sufficient in a case like that of Gareloch to keep suspended matter out of the flow ?—Yes, there are no oyster beds on the loch and in the same way with other rivers; the River Carron which enters the Forth on the east side of the country. There is a very considerable difficulty with the Carron, which is tidal for a long way. Here is the Carron, this is the Firth of Forth; (*Indicating*) there are mud banks, and the Carron enters the Forth at Grangemouth. It pursues a winding course, with a good many turns, right away up to Carron Ironworks, where a weir stops the tide. There is a very considerable discharge of sewage.

31925. (*Sir William Power.*) Is it tidal up to Carron Ironworks ?—Yes, it is tidal up to the weir. It would be tidal further up if it were not for the weir. I think there is a tide of about 3 feet, but the weir of course stops it. Well, there is a village there, Carronshore, which bitterly complains of the deposit of solid fœcal matter on the mud banks along the side of the Carron. That solid fœcal matter is to a great extent washed up by the flowing tide from a pipe from the Burgh of Falkirk, from which the sewage is entirely untreated from a population of about 20,000.

31926. Is that Falkirk at the bottom there ?—That is Grangemouth; Falkirk is further up. And then from some of our own population the sewage is treated in a fashion which is adopted for a particular difficulty existing above Carronshire. Now, we wish suspended matter taken out of the tidal part of the Carron by the Burgh of Falkirk, in the same way as we endeavour to take it out for our own area draining into the tidal part of the Carron, but we are not sure whether we could prove a nuisance under the nuisance section of the Public Health Act with regard to that deposit of excremental matter. It is very disgusting, but I believe we might have a dozen expert witnesses on one side, and a dozen on the other, and we might have difficulty in coming to a decision that the deposit was dangerous or injurious to health. The alternative would be to ask the Secretary for Scotland to declare it a stream under the Rivers Pollution Act, but then we put ourselves into the hands of Grangemouth, which could impose upon us an altogether needless degree of purification.

31927. It would be purification all the way up ?—It would be purification all the way up, and purification to the standard required by the Rivers Pollution Prevention Act, instead of a reasonable standard of removal of suspended matters.

31928. Can you give us any idea of the total sewage pollution to the total volume of the river ? Is it small or large ?—No observations have been taken on that, but it is a comparatively small river, and sewage pollution forms a very considerable ratio.

31929. It is the opposite condition to Gareloch ?—Yes, totally opposite. The Carron is a narrow river with mud banks, and not a very large volume of water in it, and the tide washes the sewage up, and the river curves so much that the tide going up or down deposits the fœcal matter on the face of the bank opposite the direction in which the tide runs. It drives the fœcal matter against it, and it lodges there.

31930. (*Chairman.*) I think most of these matters you have already given us full information upon in your statement, so that I will not ask you anything further except this. Have you found in these tidal waters any considerable development of weed growth, seaweed growth ?—No, we are not troubled with that there. No, these are just mud banks.

31931. There is just another point in regard to coal dross pollution. That has practically ceased, has it not ?—No; by no means. On the River Bonny for example, which is a tributary of the Carron, there is one colliery doing a large amount of work, where the area at the pit head is very limited, and where they have great difficulty in finding room for sufficient tanks for precipitation, and there it has not ceased. Also that colliery has changed hands repeatedly. There are large waste bings of old coal refuse, and when floods come a great deal of that refuse is washed into the stream.

31932. But you are probably aware that on the Yorkshire rivers the coal dross pollution has in effect ceased, and it has been found quite practicable to withdraw it from the rivers, and that it has also been found profitable to do so ?—Yes.

31933. Therefore, there would appear to be no excuse in the case you mention for continuing this pollution ?—No, the difficulty is with regard to old waste heaps that have been there perhaps for twenty, thirty or forty years, such as these are, close to streams; and when rain comes, a great deal of coal dross is washed into the streams independently of any present operations at the colliery such as coal-washing.

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31934. (*Sir William Power.*) It would be a costly business to remove this, would it not ?—It would be impossible to remove these heaps, and it is very difficult to deal with them. The people say: "We are not responsible; we leased these collieries five years ago. The stuff was put down twenty years ago; we have nothing to do with the rain falling and washing it into the river. We have no responsibility."

31935. (*Sir William Ramsay.*) Would it not be possible to protect them in some way by puddling them with clay ?—It would be. I have suggested retaining walls myself. My impression is that they could be protected by clay puddling or retaining walls, and by leading the water into a pond for deposit, in additon to the treatment of the coal washing effluent.

31936. (*Chairman.*) This is a purely local difficulty at that place, and I suppose the pollution would not be very serious from that source ?—Oh, yes, it is.

31937. Is it ?—What happens is this—in a case of that kind. The coal refuse gets washed down, and if there is only a moderate amount of rain, the actual refuse does not reach the main stream. It gets deposited in a rivulet between the colliery and the stream, and there is no appearance of contamination of the main stream at the time. Another flood comes, and it is washed from the bed of the rivulet into the main stream. We do not get evidence of pollution in the main stream at the time. It is a secondary pollution.

31938. Is there any point now which is not dealt with in your paper which you would like to bring before us ?—Well, with regard to the River Leven, we are in a difficulty there. The Leven discharges the waters of Loch Lomond into the Firth of Clyde, and pursues a very winding course. We have had trouble there with the Loch Lomond Angling Association. There is a population of about 20,000 on the banks of the Leven under the control of the County Council. Now, gradually this population is changing from having a dry system of refuse disposal to a water closet system, and there is a good deal more excremental matter flowing into the Leven than formerly. Well, the turkey-red dyers and the calico printers on the Leven strongly object to that on account of its making the water unsuitable for their purposes. I have thought myself whether we could establish settling ponds. The sewers run down to the Leven at about a dozen points in the course of the stream; there is no common point, and at the places where they enter the Leven some of the houses are pretty near the level of the river. We could not have filtration there, but we could have settling ponds, and collect a good deal of solid material in those settling ponds. That would suit the turkey-red people and the calico printing people, but I am not so sure if it would suit the Angling Association. The river is short; it has a fall of about 25 feet from Loch Lomond to the Firth of Clyde. Therefore, if the sewage comes straight into the Leven in a fresh condition, it gets down to the Clyde before there is time for putrefaction, but if we detained the sewage in settling ponds very likely we would get something like a septic tank effluent, which might be a good deal worse for the fish than the sewage as it comes direct. So that, on the one hand, what suits the turkey-red people is that we should have septic tanks, but that might be the very opposite of suiting the Angling Association. It seems to me a very serious thing that a body like the Angling Association can by interdict cause such tremendous inconvenience as would result if they chose to interdict the discharge of crude sewage from these populous places into the River Leven. They did serve an interdict with regard to a new population that was coming there in connection with the Argyll Motor Works. I did not object to that myself; I thought they had a good deal of reason there, but if they attempt to interdict with regard to existing populations which have been there for 150 years, the houses being close down to the stream, the resulting position would be particularly difficult.

31939. (*Sir William Power.*) Can you give us any idea of the relative volumes of the Leven water and this sewage

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you are speaking of? It must be a comparatively small amount of sewage?—A few observations have been taken as to the amount of flow in the Leven. One observation gave 32,000 cubic feet per minute. That was on a date in summer. After another fortnight's dry weather the flow had been reduced to 20,000 cubic feet per minute; at another time 60,000 cubic feet per minute was found to be the flow. Now, there is a total population there of 20,000. At 30 gallons per head that gives 600,000 gallons of sewage going into it. I worked that out, and it comes to really a very small percentage of sewage. It is a weak sewage to begin with, because, as I told you, perhaps only half the population even now is served with water closets. It is a weak sewage to start with, and there are 600,000 gallons daily to a river with a flow of from 20,000 to 60,000 cubic feet per minute.

31940. The liquid trade waste that goes into the Leven is vastly larger in volume?—Yes, when the river is at its minimum, and all the works are going up to the maximum, it is alleged that the works use one-third of the total water of the Leven, but that is very exceptional. I do not think those works ever are going at their maximum now.

31941. They return an equal amount to the Leven?—Yes, it all goes back to the Leven.

31942. (*Mr. Willis.*) What would you do? You say here that you have no hesitation in expressing your opinion that an artisan or labourer living in a house the rental of which is £10—you are speaking of the Leven?—Yes.

31943. ". . . would get much better value for his money by spending it on household necessities than by paying any such rate for purification of the Leven"?—Yes.

31944. That may be all right from his point of view, but what would you do with the owners of the fishing? Would you be content to let them be damaged? You admit they are damaged to a certain extent, but you say it would cost so very much to remove the damage; therefore, you do not agree that that great amount ought to be spent?—I cannot admit that they are being damaged; that has not been proved. It is a question of fact.

31945. Still, you say: "I am of opinion that the interests of Loch Lomond fishing, while not negligible, are not nearly worth the outlay indicated."

31946. (*Sir William Ramsay*): Are salmon going up the Leven?—Salmon are going up the Leven.

31947. Surely there are very few?—Well, I suppose there are not many. I am not an angler myself, but they are cultivating the industry rather, and they are taking a great deal of interest in it now.

31948. (*Mr. Willis.*) Although in this case there would be a damage to the fishing, I suppose it is quite clear that in some cases the fishing would be damaged, and yet the fishing would not be worth anything like as much money as it would cost to purify the sewage in order to remove the damage?—That is so.

31949. I was wondering what you would suggest should be done in a case like that. Suppose it cost £10,000 to remove the damage, and the total value of the fishing was only £1,000.—I think that would be a question of recompense to the owners of the fisheries.

31950. Would you suggest a rate should be levied on the area that is supplying this polluting matter to raise that £1,000, and that that should be handed over to the owners of the fishing?—That seems reasonable.

31951. Something of that kind?—That seems reasonable, but I do not admit myself that it has been demonstrated that there is injury there.

31952. In this particular case?—We had the benefit of an investigation by Dr. Fullerton—I daresay the Commission may know him—with regard to the whole subject, and he was very doubtful indeed whether the fish were in any way injured at the worst part of the Leven. On one side of the river there was quite a clear flow of clean water.

31953. Plenty of oxygen in it?—Yes, and he pointed out that the fish only go up when the river is high, and never when it is down to its lowest flow.

31954. But if there were a case where there was actual damage to the fishing proved, and it would cost a great deal to remove that damage—much more than the value of the fishing—you would pay the money to buy out the fishing?—That would be the reasonable course, certainly, instead of spending money on removing the pollution of the river.

31955. (*Sir William Ramsay.*) You have spoken of the Gareloch. Has your attention been turned to the rest of the Clyde? I used to have a house at Kilcreggan. You know all the houses discharge water closets into the river, the water becoming extremely yellow and dirty, with excremental matter floating about in it. Is there any remedy for that?—I remember having a correspondence with the Duke of Argyll on the subject. I advised him to try to advocate dry closets in those houses.—Yes.

31956. It used to be, and I suppose it is still, a very great nuisance all round the banks of the Clyde, this excremental matter which is being turned in on all sides?—I think a remedy is to carry the house drains very much farther out, to combine house drains where several adjoining houses suit combination, and to carry one common drain as far out as possible below low water mark.

31957. I think that is pretty well done. It was the actual excrement that used to come up on the top of the water. For bathing it was extremely unpleasant.—I am afraid it is not very universally done, the carrying of the drains out. One sees at low water a great many ends of drain pipes on the foreshore.

31958. That is quite true, but still I do not know whether that would be a proper remedy. It would not solve the question; we want to destroy this matter or not produce it.—It would be a remarkable change in the habits of the people to suggest at this time of day that water closets could be dispensed with, and a reversion made to the dry system.

31959. If ever there was a necessity for the dry system, it is there.—Yes, you cannot treat the sewage because you have the houses built round about the same short distance above high water mark, and you have a rocky soil, with no fall to any place suitable for purification works, whilst pumping would be out of the question as being too expensive.

31960. Have you heard any complaints—direct complaints—of the dwellers on the coast, as they are called?—No, not direct. The dwellers on the coast are interested in the houses, either as owners or occupiers. If they are owners they hold their tongue; if they are occupiers they know that the expense of additions would add to their rent.

31961. What about Dunoon?—That is in Argyllshire; I have nothing to do with that. I have never heard of any complaint from Dunoon, but I cannot speak of it.

31962. (*Chairman.*) Thank you; we are very much interested in the evidence you have given us, particularly by the point you raised about the discharge of sewage in its crude state as compared with the discharge of sewage after it had been held up.—Yes.

31963. One system suiting manufacturers, and the other system appearing rather desirable from other points of view?—Yes. I do not know whether the question of flooding has been before you, sir. That is rather a difficult question on the Kelvin. It is very low-lying, and a great part of the country drained by the Kelvin is flooded regularly when there are heavy rains. The people in the neighbourhood are continually asking whether that could not be remedied by clearing out the bed of the river lower down, or by removing the weir, but the responsibility does not seem to lie on any existing authority. Flooding of low-lying lands is quite a common thing along some Scotch rivers.

31964. And that again is a point that could be dealt with by a Watershed Board?—Yes, and they should have powers to get the cost made in some way. At present there is nobody who has anything to do with that.

31965. (*Sir William Ramsay.*) May I ask one more question? You said that Dr. Fullerton had stated that in his opinion septic tanks for the Leven district would produce an effluent which would injure the river?—No, that was rather my own speculation. I did not ask him, but it appeared to me it might be so. I went all along that river with the sanitary inspector, and we looked at the points where septic tanks could be put down, which would have to be underground because the houses are all close at hand, and we could not have filtration; and in looking at that, it occurred to me that at present the sewage goes straight down in a fresh condition into the Clyde, but if

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we introduced a septic tank, we might have some putrefying matter, which might be much more mischievous to the fish than the present conditions are.

31966. That is, with this present rate of flow; with the great flow of water?—The present great flow carries the fresh sewage straight down.

31967. But it appears to me that septic tank effluent would be also carried down, and would produce very little more trouble than the fresh sewage, because of the very rapid current. There is no stagnation; it would be carried down at once?—That might be so. There is some stagnation at one pool. But that is the only point.

31968. Then one other point you spoke of, and I think it wants emphasising. The Garcloch is a large enclosed body of water with a very narrow outlet. There are no mud banks on the Gareloch?—No.

31969. There has never been any sign of sea lettuce, *ulva latissima*, as far as I remember, as a nuisance?—No.

31970. There is no sea-weed cast up on the shore in any fashion?—No, I reported on the Gareloch a number of years ago, and we had at that time Mr. Pearcey from Owen's College, and he goes in very considerable detail into the algæ and so forth in the Gareloch, but he found nothing of the sort.

31971. And there is never any considerable quantity of algæ on the shore?—No, not that I am aware of.

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31972. (*Chairman.*) You come to us to-day, I think, as representing the Tavy, Walkham and Plym Fishing Association and the Tamar and Plym Fishery Board?—Yes, sir.

31973. And the evidence that you have to put before us is mainly from the point of view of the interests of the Fisheries?—Yes, mainly. I am also appearing to give evidence on behalf of the Duke of Bedford, but his interests are practically the same as those of the Fisheries. He is very much interested in them, and is spending a large sum of money annually on them, not for the benefit of his own so much as for that of the public Fisheries; but the interests are practically identical.

31974. You have taken the trouble to prepare for us what appears to be a very interesting statement, but it has reached most of us too late for us to acquaint ourselves with its contents?—I am very sorry.

31975. It might be convenient and possibly save time if you care to read it to us, and we can then ask you any questions on any points that might arise?—In reading it, I would ask you to bear in mind that I had only two days notice, and I had of necessity to go and see some of the places referred to which I had not seen quite recently, so what you will get is a rough draft as dictated to a shorthand clerk; I had no opportunity of checking it myself.

31976. If I ask you to put these matters before us you would put them at much greater length?—I could give you some facts on them; I have endeavoured to put principles except in two cases.

31977. I leave it with you to read this or put the matter before us in your own way?—May I read it? I am and have been in practice at Tavistock as a solicitor since 1885. From 1887 to the present time I have been secretary to the Tavy, Walkham and Plym Fishing Association. From 1891 to the present time I have been Clerk to the Tamar and Plym Fishery Board. In each of these capacities I have observed the various sources of pollution in the district likely to affect the fishery. The district of the Tamar and Plym Fishery Board is the whole of the watershed of the Rivers Tamar, Plym and Yealm, with their tributaries, an area irregular in shape extending 43 miles from north to south and 29 miles from east to west. The chief sources of pollution are: Metalliferous Mines, China Clay Works and Sewage Works.

CHINA CLAY WORKS.

Large works at Lee Moor discharge an effluent of a white colour like dilute milk into the Tory Brook which flows into the tidal part of the River Plym near Marsh Mills. The effluent is not poisonous, but it is sufficiently thick to destroy the fish in or drive them from the Tory Brook and to render that area useless either as spawning ground or as a fishing stream. I may add as to that that there are no fish in the Tory Brook at all.

31978. (*Mr. Willis.*) They have been destroyed?—They have been destroyed altogether.

31979. (*Chairman.*) Or driven back. Was the fishing of much value?—No; as compared to the Clay Works, certainly not. The Clay Works are very large important China Clay Works. Other works near Shaugh Bridge occasionally discharge clay water into the same river at a point some miles above the tidal part to such an extent as to prevent fishing for a time and to injure the spawn in that a deposit of very fine clay is left on the spawning beds, the effect of which is to keep the air from the ova and to prevent its hatching.

31980. Now, apart from the fisheries, is there any evil by this deposit?—I should say not.

31981. There is no nuisance created?—No, no smell, nothing offensive except that the landowners' water is not so good to look at.

31982. Is the water discoloured?—Yes. It is white.

31983. (*Sir William Ramsay.*) Do cattle drink it?—Yes; they would not hurt. This clay-water, although to the eye it is more discoloured, it is not so thick and solid as a great many of the mine pollutions that I mean to mention.

31984. (*Chairman.*) Well, will you proceed to deal with the mine pollutions?

MINES.

The most injurious effluent is that from the metalliferous mines. The district is a mining one in which there are a large number of tin, arsenic, copper, lead and wolfram mines. Not many are actually working now, but from time to time old ones are re-opened or new ones commenced. The injury is caused not so much by the water which is pumped from the mine to keep it from being flooded, as from the waste products or tailings of the ore in the process of separating the metallic from the non-metallic portions. The usual system is that the ore, as dug from the mine, is crushed or stamped in water until it becomes fine slime. The wet gravity process is most usual for separating the metal from the waste. The crushed ore in suspension in water is carried over various machines such as buddles or jiggers in which the metallic, being the heavier part, is deposited quicker, that is, nearer the point at which it is discharged into the machine, and the less metallic deposits further from that point. The tailings wash away in the water, flow into open pits known as slime-pits or catch-pits to enable more of the solid matter to settle, the effluent from which, more or less purified, flows over the outlets from these pits into the nearest natural water course, reaches the river and eventually the sea or an estuary of the sea. This process of separation is repeated until the waste is washed away, leaving the ore retained sufficiently rich to be marketable for smelting into metal. The proportion of ore so retained is less than 5 per cent., so that over 95 per cent. of that taken from the mine is discharged as waste. It is the discharge of the waste from the ore that causes the damage to the fishery and to agriculture. Sometimes, particularly from copper and tin mines in which the ore is frequently burned in process of cleaning, this waste effluent contains poisonous matter, such as sulphate of copper, soluble in water, but more often the injury is caused by the large quantity of solid non-poisonous non-soluble matter held in suspension as slime or sand. The poisonous matter kills or injures all animal life in the rivers, destroys the vegetation in which the smaller animals, the natural fish food, are bred, is injurious to the cattle which drink the water, and when carried over the land in time of flood, injures the crops. The solid matter in suspension injures the fish by suffocation, covers the spawning beds, destroys the vegetation and is injurious to the cattle and the land. The mines causing most pollution in my district at the present time are the Phœnix Mines, the Devon United

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Mines and the Bowithick Mine. The *Phœnix Mines* in the Parish of Linkinhorne, are a group of tin mines discharging effluent into the River Lynher, a tributary of the River Tamar. The mines commenced to work some forty years ago. Up to that time the Lynher river had been a very productive salmon and trout river from which salmon were taken in large numbers by nets, fixed hutches and various traps, the fishing being a considerable industry. After the Phœnix Mines started, the fish grew scarce and finally disappeared from the river. They were either destroyed or driven from the river by the mine pollution. There were no salmon in the river for some years prior to the year 1900. On the lands adjoining the river at places where it had overflowed at times, the vegetation was destroyed. I have been told by the occupiers of the lands adjoining the river that after the Phœnix Mines started the pollution some forty years ago, the number of salmon found dead in the river was sufficient to make it worth while for farmers to collect them in carts and use them to manure the land. I cannot state that of my own observation. The Phœnix Mines stopped working about the year 1900, and the river became free from pollution. The poisonous matter gradually washed out of the river bed and banks. Vegetation began to recover on the low lands adjoining the river. Salmon and trout began to appear in 1901 and 1902 and increased. The river became fairly stocked again. About a year or so ago the Phœnix Mines were re-started and the pollution has again commenced. The mines are not yet in full work, but the decrease in the number of salmon has already been noticed. It is something like 12 miles from the tide where the pollution from these mines enters the river, and at places the river passes through low lying meadow land, particularly useful to farmers in dry summers. The worst effect of the pollution, so far as agriculture is concerned, is that it silts up the river bed so that as soon as any flood comes, after heavy rain, the river overflows the banks and carries with it on to the meadow land adjoining a lot of, sometimes poisonous, always useless, harmful refuse which renders the land on which it is deposited of no agricultural value. Nothing grows on it except perhaps rushes or very rough vegetation, and it takes years, as a rule, for that kind of land to recover even after the pollution has ceased. The injured meadow land adjoining the River Lynher has not recovered now.

31985. You say this flood is directly a result of a deposit from the mines ?—Of the deposit from the mines partly filling the river bed. The moment a flood comes, there is no room in the river bed to take the extra water which has to overflow, and carries with it these mine deposits.

31986. And during the stoppage of the Phœnix Mine, did you find the flood reduced ?—Yes, the river was clearing itself ; the bed of the river was clearing itself.

31987. (*Sir William Ramsay.*) Has the water in the river ever been analysed ?—I have a copy of an analysis here, but not of a very recent sample.

31988. During the working of the Phœnix Mine, I mean ?—Yes. It was taken when I made a complaint to the County Council of Cornwall 4 or 5 years ago about that mine pollution. I asked them to put in force the powers of the Rivers Pollution Act, and they found that they could not, under Part III. of the act, as against metalliferous mines, spend the public money in a prosecution or in any action without the consent of the Local Government Board. They applied to that Board for leave but leave was refused.

31989. (*Chairman,*) You were going to say something to us about the River Tavy ?—The *Devon United Mines* in the Parish of Petertavy on the bank of the River Tavy cause considerable pollution and injury to the rivers and lands adjoining the rivers below. They are Tin, Copper and Arsenic Mines which commenced working about 1902. The ore is raised from shafts and underground workings and treated and cleansed by the process I have described as the wet gravity process. At the instance of the Local Fishery Board with the view of diminishing the pollution the owners have constructed some catch pits which if used to their fullest extent would not be sufficient to effectively deal with the solids in the effluent as the pits are not large enough. Small as they are they are not used to their fullest extent, consequently an enormous quantity of silt and slime is discharged into the River Tavy. Farmers owning and occupying land adjoining the river below, deem they suffer serious loss from the pollution in that the water being their drinking water supply of their cattle, causes injury to the cattle. The fish in the river are destroyed or driven back. The spawning beds are ruined and the fish food supply is destroyed. I have here a sample of the water taken from the river bed immediately below the outfall from this mine. This was taken on Saturday when the conditions were as good and probably better than I have seen the effluent for the last two years. It is usually much thicker than the sample. (*Bottle of effluent produced.*) That is not quite the effluent as it leaves the mine ; that is as I got it from the bed of the river below ; there is a little river water with that.

31990. Do you suggest that is a sample of the river after it has received this effluent ?—I took that out of the river. The effluent comes over a rushing shoot ; I placed my bottle in the bed of the river.

31991. This is a sample of the effluent ?—That is not pure effluent ; there is a little river water with it.

31992. This is substantially effluent ?—Yes.

31993. There is a considerable dilution afterwards ?—In the river, yes, but this is diluted to some extent.

31994. How soon will the suspended matter in the bottle settle down ?—It would not get quite clear for weeks, because, as I have described later, the white substance which you see mostly at the top, where it is free from sand, is mica, and I do not think any settling can actually get rid of all of that. It would have to be filtered. Filtration for this kind of pollution has been carried on in our district under my own observation at other mines.

31995. Then, it is mostly flocculent matter which is carried down the stream ?—It is all carried down the stream ; the whole of that is carried down the stream ; the Tavy is a moorland stream.

31996. At any rate it does not settle ?—Not the whole of it. Something like seven-tenths of the bulk of this is sand-slime ; that is heavy crushed-stone. Although there is a good deal of mica colour in it, you will find seven-tenths, certainly considerably more than half of that, would settle in a few hours. By the time you leave to-day, you will very likely see there is a quarter of an inch of solid sediment at the bottom of the bottle. The water above would still look coloured unless it is filtered.

31997. Then, the instances which you are going to give us and which are set out in your paper, and which perhaps it is not necessary for us to go through, are all similar pollutions arising on different streams ?—I have only given you the one I am now reading and one other. I have dealt with only those which are at present causing damage above the tide. Many of our mines discharge into the tideway.

31998. But is the character of the pollution the same ? Not in the other instance I am giving you above the tide. It is quite different. I would like to mention that, if I may.

31999. Well, deal with that ?—The *Bowithick Mine* is worked by the Legeh Concessions Limited near Altarnun, Cornwall, on the upper portion of the River Inney a tributary of the River Tamar. It commenced working about the end of 1906 or beginning of 1907 for Wolfram or Tungstate-of-Iron. There is no actual mining, that is there are no shafts or underground workings but large, apparently alluvial, deposits on the surface of the earth are washed out with water forced at high pressure through moveable hose terminating in nozzles like fire engine nozzles but larger. The force of water is obtained by taking it from a much higher level, not by using force pumps. The Wolfram in small solid blocks not mixed with any other metal or mineral, is found in beds of granite and quartz, gravel and sand. The Wolfram bearing deposits are of a depth of from 2 to 18 or 20 feet and extend over large irregular shaped areas. The process is by force of water to wash down the stones, gravel and sand containing the Wolfram, to pump it into flumes ; a stream of water running through the flume washes away the rocks of granite, the gravel, and quartz, leaving the Wolfram in the bottom of the flume. The owners have washed out several acres of the deposit to a depth of from 2 to 20 feet and are continuing to operate in the same way. They are also using, or about to use, a machine-digger for working other deposits lower down the valley. Of the deposit dealt with not more than 1 per cent. is saved. The remainder is discarded as waste and most of it finds

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its way into a river called the Penpont Water, a tributary of the River Inney. After repeated complaints by the Fishery Board and others, two catch pits were constructed but they have not been used to any great extent. They are not anything like adequate to deal with the quantity of solid matter discharged from the works. They are in such a position that the ordinary flood water after rain washes a great part of the slime that may have been kept back in them into the river. A large heap of these waste slimes that I have observed has diminished in this way so that less than one-third of its original bulk remains. The rest has been washed into the river. The effect of this pollution is that the river bed is blocked with gravel and sand for some miles below the mine. The level of the bed of the river and of the low land adjoining has been raised some 4 or 5 feet by deposits of mine slime. When the river rises after rain, it overflows its banks much sooner than it would have done before the silting up and the polluted stream overflows the land adjoining to varying width, filling all depressions with mine-slime and sand and doing considerable damage to the crops. At the farm next down stream from these works, the difference in levels of the river bank on the farm side and that on the other, which is common land, was such as to be sufficient to keep the commoners cattle out from the cultivated land. The mine refuse deposited has brought the level of the common to about the same as that of the farm so that a fence has had to be constructed on the top of the high bank. In the next farm further down stream, the river bed has been raised some 4 or 5 feet all depressions in the lands near have been filled with mine slime and this slime is deposited over the surface of the land, damaging it. A field on this farm adjoining the river had been artificially drained with earthenware pipes. The outlet from these drains was some 1½ feet above the water level before the mine silting commenced. A few weeks ago when I saw it, the outlet was covered with slime and sand to a depth of about 2 feet rendering the draining practically useless. The whole river bed, river bank and water level has been raised to the same extent so that if the outlet of the drain were cleared, it would not drain as the normal flow of the river is at a higher level. The water in the river whenever the mine is working is thick with grey slime and sand for some 5 or 6 miles below the outlet from the mine, so thick as to be injurious to cattle that drink from it. The river water was until the mine started used for general household purposes, other than drinking by most of the inhabitants of the village of Altarnun, some 6 miles below but now the stream is so polluted they fetch all their water from the drinking supply which is much farther away. The pollution by this mine causes general complaint by most of the persons owning or occupying land adjoining the river for several miles below the mine. The effect of this pollution on the fishery is that all fish life has been destroyed in the Penpont Water below the mine. All or nearly all the water vegetation which supplied food for the fish there and below has gone. Only a few traces remain. The fishing in the Inney below where the Penpont Water joins it, is much injured, the number of fish there is noticeably less than formerly, their food supply is less and it is only when the mine may temporarily be not working that the river is in a fit state to fish. The fishing in the Tamar some 15 miles below is injured in the same way only in a less degree as the pollution becomes more dilute. The 15 miles of Inney with its tributaries is now of little or no use as a spawning ground for fish or as a source of supply of fish food. The scour or rush of the Penpont Water and Inney is such that practically all the silt and slime is eventually carried down into the Tamar whence it finds its way into the Hamoaze and Harbour of Devonport. On its way there it deposits on the spawning beds, causing suffocation to the ova and destroying the fish food. It is impossible to observe or measure the damage in the Tamar but it is undoubtedly very great. I have given particulars of those mines only which are at the present time discharging into the rivers above the tidal portions, the injury from which can be more readily observed. Several mines in the district are working and discharging pollution into the tidal portions of the rivers the effect of which is not seen. There is some injury from this pollution but its extent is much less in that the pollution is discharged into a larger body of water and becomes immediately more dilute. At the present time there are fewer mines working in the district than at any time within my memory. Others I know are about to commence new work or to resume old works, notably a large one at Marytavy on the banks of the Tavy which has stopped temporarily while a new company is being formed to work it. The powers of Fishery Boards to prevent pollution from mines are those conferred by Secs. 5, 6 and 7 of the Salmon Fishery Acts, 1861. They are of very little use. The chief remedy is that of a small fine for each actual killing of fish by pollution even when the difficulties created by the word "knowingly" in the 5th Section are overcome. Evidence of the actual killing by pollution is very difficult to obtain unless the poison is sufficiently strong to kill the fish instantly which seldom happens. If it does happen one could not proceed with success unless a witness were available who was present at the time. The habit of fish, when they meet poisonous water, of going down stream before it or "tailing back" as it is called, with the result that when they die they are usually found a long way from the source of the pollution, tends to make the obtaining of the necessary evidence difficult. I have not found the Rivers Pollution Act of much help to the Fishery Board in their endeavour to prevent pollution from mines. Its powers as to mine pollution can only be put in force by the Sanitary Authority of the district, *i.e.*, the County Councils with the sanction of the Local Government Board, and the words of Sec. 4 have been held only to apply to "noxious" or "poisonous" liquid. It is held that to be "polluting" within the section, the matter must be "noxious" or "poisonous." It is so provided by Section 20 of the same Act. This Fishery District is partly in the County of Devon and partly in Cornwall. The County Council of Devon have never so far as I could ascertain taken any steps in response to applications by the Fishery Board to enforce Section 4. The County Council of Cornwall have endeavoured to help and applied to the Local Government Board for leave to take proceedings against a mine company for committing a breach of that Section. In one instance an enquiry was held by the Local Government Board but the leave was refused. The only other remedy at present is by Civil Action in the High Court, a costly matter which very few Fishery Boards have funds available to meet. That a remedy should be provided is evident. At present unless some owner of private fishery will on his own behalf and at his own expense take action against the mine owner causing the injury, a small mine employing only a few hands may with impunity ruin a fishery which is a much larger industry, finds permanent employment for a much larger number of hands and is of greater public benefit. We have a case in point in my district at the present time. The owners of the Bowithick Mine before mentioned who do not I believe employ more than 12 or 15 hands (I have never seen even that number on the works at one time) are for lack of proper care and some expense very seriously injuring the fishery of the whole district, a fishery which in the salmon netting in the tidal waters alone provides employment for over 100 men. The value of and the amount of employment provided by the private fisheries above the tidal parts of the river are much more than those of the net fishery. I hesitate to suggest a remedy and do so with great diffidence. I think that the Law should be such that any person opening or working mining or other works on his land should be compelled to so work them as not to injure his neighbour. He should be compelled, without restriction of cost, to keep on his own premises, or discharge without doing injury all effluent or waste product whether it be acids or solids in water or acids or gases in the air, if that waste injures his neighbour. The broad principle should be established that any mine owner injuring his neighbour, without sufficiently compensating him, could be stopped by injunction, at the instance of any injured party, by some summary procedure at small cost. How such injury as we suffer in my district may be nullified are engineering and chemical matters which vary in the case of each of the industries causing the injuries as the contents of the various effluents vary. There is no real difficulty about them. It is chiefly a matter of expense. More injurious and much larger effluents than those I have described have been satisfactorily dealt with by mines in my district within my knowledge. For instance the sulphate of copper solution has been extracted by running the effluent over metallic iron on which the copper deposits itself. Some mines did this and made a profit by so doing. Other poisons in solution have been extracted after precipitation. The solids in suspension can be satisfactorily dealt with in most cases by passing through settling or catch-pits. It is mainly a question of a sufficient area of catch-pit and of proper cleaning. In some of the effluents, some portion

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of the solids in suspension is sometimes so light that it does not readily settle in catch-pits. It requires too long a time. For instance a good deal of that in the effluent I have referred to from Devon United Mines is very light. It consists apparently of fine particles of mica. A similar substance I have known to be extracted by another mine in my district by filtration through gravel beds and coke. I have with me some Analysts' Reports and copies of others of analyses of various mine effluents made in my district from time to time. They are only of interest to show the contents of the pollution which usually occur in that district. I am not sufficient of a chemist to suggest the appropriate reacting agents.

32000. (*Sir William Power.*) The river has been raised 5 feet in five years by this detritus ?—For some distance, yes.

32001. 1906 ?—Of course, it is a very small stream at that point ; it is a brook.

32002. What is the width of the river there ?—Oh, it is perhaps 8 or 9 feet wide ; it is nearly on the top of the Cornish Moors. It is on the side of Roughtor and Brown Willy near Camelford.

32003. (*Chairman.*) You may pass over any similar cases of pollution and deal with any special point ?—I have no other. I have not given you any others because I thought it was best only to give you those that were really doing the damage at the present time, and I cannot say that those discharging into the tidal portions of the river are really doing much damage ; they no doubt do a little.

32004. The damage appears to be two-fold ; to the fisheries and to agriculture ?—Yes.

32005. You are interested especially in representing fisheries ?—And agriculture, as representing the Duke of Bedford.

32006. It would be interesting to have some idea of the relative value of the mining, on the one hand, and of these fisheries on the other. These rivers are not rivers of any length, are they ; they flow soon into the sea ?—They go into Plymouth Sound. Tavistock is about 14½ miles as one drives ; perhaps 17 miles as the river goes—rather more. The fishery is pretty big in that. There are 20 authorised Salmon nets working the public fishery in our district at the present time. That means a permanent employment for at least 100, probably 120 men. It takes four or five men generally to work a net. They work those nets at considerable profit which keeps them ; and is practically their only means of livelihood.

32007. If, in these processes of mining they are only able to utilise from 1 to 5 per cent. of the material which they are washing, and send the whole of the remainder into the river, it would evidently be an exceedingly costly thing for the mine-owners to keep that matter back, would it not ?—It would be costly.

32008. Probably prohibitively costly ?—I think not, because in my experience, and I have been mixed up with mines a great deal, it is usually the smaller mine, the mine that is not making much profit that does the damage. The other mines—the larger *bona fide* industries, as a rule—have not given us so much trouble. Although they have created more effluent and, as a rule, more poisonous effluent, they have dealt with it in a more satisfactory way ; they have been able to deal with it, they have had the money to do so.

32009. It is interesting to hear that some of the better mines have remedied this evil themselves ?—Much worse pollution than we have at present.

32010. Do you suggest it is reasonably practicable for all mines to do this ?—All mines in our district certainly.

32011. And that it would not extinguish the industry if pressure were put upon them to carry out such works ?—I cannot say. One or two of them are not paying ; they may not be paying much. Bowithick Mine has never paid. It might be that this little extra for keeping this pollution out might stop the mines altogether. They are not doing any good for themselves in the way of earning dividends ; they have not earned dividends at all.

32012. But you would compel them to stop pollution, whether it meant shutting them up or not ?—I think so.

32013. Do you think that is the right thing ?—I do not think they have more than ten or a dozen men working while the net fishing alone is an industry for over 100 men, and the net fishery is not a quarter of the whole fishery.

32014. In this particular case, the fishery is a much bigger thing than the mine ?—Yes.

32015. And more important ?—Much more so.

32016. (*Chairman.*) What is the area of your Fishery Board ; it seems to extend over the watershed and to include all these little rivers ?—They are all within our area.

32017. What are your powers as a Fishery Board ?—As to pollution they are practically nil.

32018. (*Mr. Willis.*) You have to prove that a particular fish died from a particular pollution ?—Yes, we have, under the Salmon Fisheries Act, 1861. I have set out some of the reasons why the provisions of this Act are useless to us. We have practically no remedy unless we can get a land-owner or some private owner to intervene.

32019 By an action at common law, you mean ?—By an action for damages or for an injunction ; an ordinary civil action in the High Court.

2020. What would be the ground of his action ; not injury to fish, but to agriculture ?—Injury to agriculture or fish, personal injury, injury to property.

32021. Do you find, in fact, that you cannot get private owners to undertake such actions ?—No ; I have never had one in my time.

32022. (*Sir William Ramsay.*) Is the difficulty because the district is partly in Cornwall and partly in Devon ?—Oh no. The Devon County Council never has helped us ; but the Cornwall County Council has tried to utilise the powers of the Rivers Pollution Acts as I have before mentioned but without effect. The Rivers Pollution Act, so far as mine pollution is concerned is of no use.

32023. And there is nothing in the shape of a Rivers Board, of course ?—No.

32024. If that were done, would not the conservation of the river be their chief object ?—I should think it would be, but they would require to have more power.

32025. (*Chairman.*) You say the Cornwall County Council have striven to remedy this evil, and they have found themselves helpless in the case of the mines ; how is that ?—Because of the provisions of the Rivers Pollution Prevention Act. The part of that Act dealing with mines is Part III. which says : "Every person who causes . . . or knowingly permits to fall or flow . . . any poisonous noxious or polluting matter shall be deemed to be guilty of an offence." The word "knowingly" has been held to apply to "Poisonous" and the clause "poisonous noxious or polluting" has been ruled to apply only to matter which is "poisonous." It is not enough if it be harmful or polluting.

32026. (*Mr. Willis.*) Has that been ruled in the High Court, do you mean ?—Yes, I believe so.

32027. "Poisonous, noxious and polluting" ; to come within this Section, anything must be poisonous or noxious which is polluting.

32028. (*Sir William Ramsay*). I should have thought it depends on the meaning to be attached to "noxious." "Poisonous" means harmful ; "noxious" means harmful ?—It is not sufficient to obtain a conviction that the matter be either poisonous or noxious or polluting. It must be all three as polluting is deemed to mean noxious. From what the Local Government Board Inspector said at the Inquiry about the Prince of Wales Mine, I judged that was the reason why he reported not recommending the Authority to use the money for the prosecution of that mine although the formal refusal was stated to be on general grounds.

32029. (*Mr. Willis.*) May I look at the date of that Inquiry ?—I have the Report of it here, 1901, September, I think the 20th. I am taking it from a newspaper of Friday the 27th. It says "last Friday" ; that would be the 20th September, that they actually sat.

32030. The Local Government Board refused their consent to this prosecution, did they ?—They did. I think the Act says they must be asked for leave and leave was not granted ; leave was refused.

32031. And they did not give any reasons, I suppose ?—I can give you some information. I have somewhere a copy of the letter that they sent to the County Council refusing the leave. This letter stated that the County Council had not satisfactorily proved that the Company had caused . . . or knowingly permitted to fall or flow . . . any poisonous noxious or polluting liquid from the mine. Having regard to that conclusion and the industrial interests involved and the circumstances and requirements of the locality the leave asked for was refused.

32032. Of course, you know that under the Act, the Local Government Board are not allowed to give consent unless they are satisfied that means are reasonably available and practicable for rendering the stuff harmless ?—Yes.

32033. If that is not proved, then they are precluded from giving consent ?—Yes, I know that.

32034. I do not know on what ground they refused consent, but it may have been on that ground that the promoters of this action did not show that it was in the case brought forward reasonably practicable and available to adopt purification measures ?—I can only give my impression from what took place at the Inquiry.

32035. It was not refused on the ground you were mentioning, that this liquid is not proved to be "noxious poisonous and polluting." It says "noxious, poisonous or polluting" in the Act ?—I think you will find "poisonous and noxious" are the ruling words. Sec. 20 of the Act states that "polluting" in Sec. 5 means "noxious" which has been ruled to mean poisonous. From what the Inspector said at that Inquiry, it seemed that he was satisfied that the poisonous matter could be retained. The mine referred to is the only one I have known where in recent years they have taken measures to retain the poisonous matter, but there the poisonous matter is sulphate of copper, which of course is very easily retained. At the Prince of Wales Mine, which is the mine where this Inquiry was held, they had a system of deposit pits, for depositing the sulphate of copper on metallic iron which they were working. I do not say they were working these pits on purpose to keep the pollution from the river, but they were working them and at a profit. The copper deposited on the iron in these pits, after they had finished with their effluent in every way, was a source of profit to them. And there they had plenty of room to use catch-pits. They had some catch-pits and they had plenty of room for more catch-pits.

32036. (*Chairman.*) I wish you could tell us exactly what was the reason why this action of the County Council failed; why the Local Government Board did not give consent ?—I am afraid I cannot.

32037. (*Mr. Willis.*) Mr. Mathews has not that information ?—I never had that information.

32038. (*Chairman*). That is the only attempt that has been made by the County Council of Cornwall to deal with these matters ?—That is the only attempt in which they have gone so far as an Inquiry. We tried to deal with the Phœnix Mines, but the Committee of the Council, remembering the inquiry as to the Prince of Wales Mine, did not recommend them to go to an Inquiry; they thought it was useless.

32039. The County of Devon have not taken any action ?—No.

32040. You are in this position; your Fishery Board has no powers and the County Councils cannot do anything ?—That is so.

32041. In the one case, where the County Council tried to do something, they did not succeed ?—That is so.

32042. Did the Devon County Council ever do any thing ?—No. I did make one application. I did not get an official reply, but a member of the Council told me the matter had been considered, and the County Council could not interfere with the Fishery; they could not help the Fishery; some message of that sort; they never did anything.

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32043. (*Sir William Ramsay.*) Have members of the County Council any personal interest in these mines ?—Not so much as the local people in Tavistock would have. It is a large county. All are interested in the mines, interested in keeping them going, they are the mainstay of the district, but the Fishery Board are satisfied that these mines, particularly those that lately have been doing most injury, could, if they would spend the money on it, keep the hurtful matter, whether it be poisonous or merely solids in suspension, from the river.

32044. What would be done with the material in the catch-pits ?—It takes a good deal of the material to enlarge and continue the catch-pits. It would not all be required for the purpose. What was not required would have to be taken away as waste.

32045. It must be dug out ?—It must be dug out like most of the mine refuse is. No doubt you have seen the very ugly heaps that we get with the mines in our district.

32046. (*Chairman.*) Then, in any case, a portion of the suspended matter in the effluent is so light that it is not likely to settle in catch-pits. Could it not be dealt with by the mine-owners ?—Yes, it has been dealt with by another mine farther down the River Tavy.

32047. How do they deal with this lighter matter ?—They pass it through filter beds; something like rough sewage filtration beds, and if necessary they afterwards run it through coke. At the mine where some portion of the effluent was treated in this way, the treatment for some time went on very effectively, but it wanted attention. I think there would not be so much complaint of the mere colouring matter in that mining district; it is the killing quantity of solids that is discharged that really is such a cause of complaint.

32048. The poisonous matter, you think, could be withheld without cost to the mine owner ?—Well, I expect it would cost them something to keep it all out.

32049. Anyway, your opinion is that it is practicable to remedy this evil ?—It is; it has been done. There was a mine called Lady Bertha near Tavistock; it was close to the banks of the Tavy; it discharged a lot of polluting matter into the river, solid matter in suspension, and it also discharged poisonous matter, but the owner of the land insisted that the mine should so discharge its effluent that they did not injure his other tenants below them. The measures taken were rather unusual methods, but they did prevent injury to a great extent.

32050. We thank you for the interesting evidence you have brought before us, which will be carefully considered by the Commission ?—There was just one matter I thought I might like to mention, the flooding of old shafts. We have had occasionally very severe destruction of fish from that, but I do not know how it is to be dealt with. An old mine shaft that perhaps has not been worked for hundreds of years gets full of water and it soaks for years all the poisonous matter that is soluble out of the sides of the shafts and it becomes highly concentrated poison, and then from some accident or flood, a lot of flood water is suddenly discharged into this shaft and then it overflows, and a tremendous destruction of fish follows. It is impossible to prevent that except by filling in the shaft.

32051. (*Mr. Willis*). I suppose the owner of the shaft would be legally responsible, would he not ?—I do not know.

32052. I do not mean under the Rivers Pollution Act ?—The Rivers Pollution Act does not deal with that.

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32053. (*Chairman.*) You are a landowner on the River Inney ?—Yes, sir.

32054. You have known the river for some time ?—Between five and six years.

32055. What is the extent of river which affects you ?—Four miles.

32056. And it affects you chiefly in regard to the fishing ?—Mainly so. If the water in my part of the river becomes as it is up above, it will affect my tenants, because I have heard that cattle and horses near the source of the evil will not drink the water up there. So, owning land on the river, if the pollution so much increased that the water where it runs through my land

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becomes so thick and polluted as it is up there, it will affect my tenants.

32057. So it affects you from those two points of view, fishing and agriculture ?—Yes.

32058. Will you explain to us what is the nature of the evil of which you complain ? Would you prefer to read the statement you have put before us ?—I have a further statement here, or I can give it from some rough notes I have.

32059. We are unable to spend too much time over this.—I see. I have known the River Inney and its tributary the Penpont Water for some six years. The river passes through my land for the extent of about four miles and I own the entire fishing in it for that distance. When I first knew the river, before I succeeded to the property and after, at normal times it was an unpolluted moorland river or stream and contained very good fishing. The Penpont tributary of the Inney has been, since some time in the autumn of 1909, very much discoloured by mine slime. This I have ascertained proceeds from the works at Bowithick of the Legeh Concessions Syndicate Limited. The pollution from those works has been increasing and getting more and more until now, I believe, the fish in the Penpont Water for some distance below the mine must be absolutely destroyed. The fishing in my part of the Inney which is some six miles below Bowithick is very much damaged, so much so that I have not ventured to let the fishing to a tenant this year as I had the opportunity of doing and wished to do. The quantity of solid matter coming down the river is such as to cover the spawning beds with silt to such an extent as to destroy the spawn. Further it has had a disastrous effect upon the natural food bearing plants in the river and destroys the fish food. I have examined the Penpont Water from where the Bowithick works are carried on for some distance downwards. The method of working is washing out a quantity of gravel, slime and sand from which something is extracted for mineral purposes, but the great bulk is allowed to run into the river or kept back by some very small inadequate catch pits. These catch pits are, I believe, inadequate in that they do not and have not kept the solid matter from the river.

32060. Does not this really give all that is necessary to put before us ?—I might say I am endeavouring to let the mansion house and the ground, the sporting right, and in the letting I consider the fishing worth £100 a year. My late uncle could have got that for it, and refused to take it. The pollution is increasing considerably, and last May I saw the river quite twenty days out of thirty, and on only one or two of those days would it have been possible to fish, and I am not sure it would have been possible even then. It was then only possible to see the bottom of the river in the very shallowest places. I consider the whole value of the fishing rent is the amount of damage to me ; and also instead of having a nice clean stream running through the property—and it is one of the beauties of the property of course—I have a dirty muddy river.

32061. (*Sir William Ramsay.*) Quite recently this has happened ?—I first noticed it in the autumn of 1909.

32062. (*Chairman.*) Tell us from what cause it arose—this change in 1909. What led to it ?—I found there was something wrong with the river, and I heard there was a mine working on the moor. I went up to see what this mine was doing, and I found it was sending down an enormous amount of sand and gravel and lime into the river. It was extracting a certain amount for mineral purposes ; the whole of the rest was coming down the river.

32063. Was this a new mine that had not been worked before ?—Yes, it had only been worked before on a very small scale with about three men, from what the local people saw of it. It was a mangle crusher, with the men wearing rubber boots. There was no machinery of any sort.

32064. No trouble had arisen from that small working ? —No, no trouble at all.

32065. Now, what is the extent of the present working since 1909 ; is it extensive ?—It is very extensive. I have heard—I do not know whether it is so—that they have spent something like £15,000 on machinery. They have got a dredge which is now working, which the manager himself told me cost £7,000.

32066. Do they employ many persons there ?—I was up there last Friday, and I heard they were employing sixteen.

32067. (*Mr. Willis.*) Not very many ?—No. When there is more water, they may employ more. At the present moment they are very short of water. The result will be that when there is more water, the river will be worse than ever.

32068. Have you complained to them ?—I have complained to them, both to the late Manager and the present Manager and Secretary of the Company. They say they are doing all they can.

32069. Do they deny that the nuisance you are suffering from is caused by them ?—The Secretary does not deny it at all.

32070. You have not threatened to bring an action against them I suppose ?—No.

32071. (*Chairman.*) Are there any other mines on the stream ?—None which affect me. I do not think there are any other mines.

32072. (*Sir William Power.*) Where do they get their water from ? From the stream, or is it a private supply ? —From the stream. In 1910 they built a reservoir on the hill, and now that water is brought down in great iron pipes and made use of below.

32073. Is water impounded from the stream ?—Yes. That water I was told by the Manager takes 16 hours to run into the reservoir. It is all let out through a small nozzle in 8 hours.

32074. (*Sir William Ramsay.*) Is that for washing down the soil under pressure ?—For washing down the soil under pressure.

32075. Are there other proprietors on the banks besides yourself who are also suffering ?—Yes, up above me there are farmers mainly. Below me there are one or two others who own more of the river who are suffering considerably.

32076. Have you any idea of taking concerted action ? —Well, I do not know. There has been something said about it. I daresay that will be what will finally happen. I think the only thing which deters people is the expense, a great many of us.

32077. (*Mr. Willis.*) Have you brought your particular case before the County Council ?—No.

32078. You might do that, and ask the County Council whether they could not take action under the Rivers Pollution Prevention Act ?—I am perfectly sure myself the fish are decreasing. As I say, I have known the river for about five years. I have fished constantly when it was fishable, and you could see the fish coming out from every stone and every little bit of wood, but last summer while they were building this reservoir my keeper and I walked up the river on two or three occasions, and we hardly saw any fish at all ; not more than three or four where before we had seen a hundred.

32079. (*Chairman.*) Is there any other point that you would like to put before us ?—I might say, just to show you the enormous quantity of slime and sand they are sending down, that about a quarter of a mile below the mine there is on one side of the river a common, and on the other side a cultivated farm. The level of the common was so much below that of the farm that the river acted as a boundary between the two, and cattle could not get across. The slime has come down in such an enormous quantity that those levels are practically equal now, so that cattle could walk across from the common to the farm. The consequence is the mine people have had to fence off the farm. There was also a five-barred gate, which was an entrance from the common to the farm. That gate was so heaped up that there were only the two top bars showing, and it had to be removed five or six feet back on the cultivated land, so that the river bed for about a mile there is entirely altered, and where cross-hedges adjoin the river there is such an accumulation, or where the river has any obstruction at all there is an enormous quantity of sand on each side of it. Wherever there was any little crevice, or any place where it could deposit, it has rested there.

32080. Can you express any opinion as to whether it is practicable for these mine-owners to keep back this material which they send down into the river ?—I cannot

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express an opinion. I can only express the opinion—I do not know whether it is allowable—of the present Manager of the mine. He told me he has seen it done abroad, and he did not think it would be a very costly matter.

32081. You have no special knowledge yourself as to these matters ?—No, these catch-pits which they have got now are immediately in line with the river. The river runs right through them. I went up three weeks ago, and the river was coming down worse than ever. I went up and saw one of these catch-pits; they are only dammed up with sods of turf which has broken away, and down came an enormous amount of stuff; about 8 feet of stuff which had been ponded back. All this in flood time is bound to come away; all this sand deposited near the river, when a flood comes, is washed further down.

32082. In putting before us this evidence as to the damage which is done to you by this particular mine, you say that it is very difficult for you to take any remedy to stop it, because of the great expense that would be involved ?—Yes. If I could see my way, so to speak—get the money for it—I should have no hesitation, because to the property, particularly a property which has to be let, it is terribly detrimental.

32083. Thank you. Your evidence will be carefully considered by the Commission.

Mr. Harold Gaye Michelmore, Clerk to the Teign Board of Conservators; and Mr. T. Pitts Rowell, called in; and Examined.

Mr. Harold Gaye Michelmore. and Mr. T. Pitts Rowell.

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32084. (*Chairman.*) Mr. Michelmore, you have come before us as the Clerk of the Teign Board of Conservators ?—(*Mr. Michelmore*). That is so.

32085. And you, Mr. Rowell, I think come before us to give evidence of a personal character ?—(*Mr. Rowell.*) Yes, sir.

32086. Both dealing with the River Teign ?—(*Mr. Michelmore*). Mr. Rowell deals with the Lemon, which is a tributary of the Teign. They are both within the Teign Fishery District.

32087. I see the statement in our hands is quite brief. It might be convenient for you to read it ?—Yes. The principal rivers which fall under the jurisdiction of my Board are the River Teign, the River Bovey, and the River Lemon. The Rivers Bovey and Lemon are tributaries of the Teign. The River Bovey is not polluted to any serious extent. It is occasionally discoloured by dirty water from the Bovey Pottery and it is also somewhat affected by the outfall works of the Bovey Tracey Sewage Plant, but in neither case to any serious extent. The River Teign is subject to various pollutions, but speaking generally the higher reaches have improved in recent years, whilst the tidal portions are in a much worse condition. Two mines, namely, The Great Weeke Mine at Chagford and the Canonteign Mine between Ashton and Trusham have ceased working for some years and it is not thought that they will be restarted. The Great Weeke Mine was a tin mine and the Canonteign Mine a silver and lead mine, and both caused serious pollution to the river. The present pollutions are caused by: (1) The Teign Barytes Mine at Bridford; (2) Clay Works at Bellamarsh (Chudleigh), Horse Mills (Kingsteignton) and Teignbridge; (3) Newton Sewage in which is included all the refuse matter from a large tannery; (4) Teignmouth Sewage. No. 1, formerly turned the whole river a milky white and left a considerable sediment of white slime upon the bed of the river. Arrangements have now been made by my Board with the Company working the mine to form catch-pits and only to turn out the catch-pits in times of flood. This arrangement has effected a very great improvement. No. 2 turns the river to a white colour for some little distance, but does not leave much deposit. The reason that the pollution from the clay-pits is not more serious is that the water which they pump up is originally derived from surface drainage, so that it is only in times of wet weather that they pump any great volume of water and the river is usually then in flood and much better able to carry it off than when the weather is dry. No. 3 is a most serious pollution. The sewage is frequently allowed to flow into the river in an almost crude state and the effect of the tan water upon any fish entering the river is very bad.

32088. (*Mr. Willis*). Is the river tidal at Newton ?—It is tidal I think a mile above Newton.

32089. It discharges into tidal water ?—It is a very narrow river there. It is practically above the estuary, but it is still tidal. Any water you get there is practically fresh water bayed back, and it might be a little brackish.

32090. There is a movement of the tide above the point where they discharge this sewage ?—Yes. No. 4 is also bad, but as the outlet is in the harbour where the water is salt, the effect is not nearly so bad as No. 3. The River Lemon is subject to serious pollution from a mine belonging to Mr. Bayldon and as to this, I understand, that Mr. Rowell, one of the landowners on the river, will give evidence in detail.

32091. (*Chairman.*) What is this Board of Conservators, and what powers has it ? What is the area of its jurisdiction ?—Its jurisdiction is the River Teign and all its tributaries, and all rivers flowing into the sea within an area of about 10 miles around its mouth.

32092. How came this Board to be formed and when ?—It was formed under the Salmon Fisheries Act, 1861, when most of the other Boards were formed. What I wish to call your attention to is the want of power we have to deal with this pollution when it arises on the River Teign. We are not suffering very much at the present moment, but we have suffered, and if we suffer again we have really no powers to protect ourselves.

32093. (*Mr. Willis.*) Could you not call the attention of the County Council to the matter, and let them take action under the Rivers Pollution Act ?—I do not think it is much use. The County Council is a busy body.

32094. If the Local Authority has powers, and will not use them because it is too busy . . . ?—It is a case as a rule which calls for immediate action. We could not hope to get anything done by a County Council for twelve months, and in that time the damage would be done.

32095. In the West Riding of Yorkshire they have a joint body, really a combination of County Councils with inspectors and so on, enforcing the Rivers Pollution Act daily ?—We have nothing of that kind in Devonshire. I do not know their procedure, but I think such a matter as this would first go to a Committee, which would then report to the next meeting of the Council.

32096. The methods, you think, are not suitable ?—It seems to me the Local Boards upon the river are the people who should have the power to deal with any pollution on that river. We hear of it directly it starts, and we know what damage is done.

32097. (*Chairman.*) Your Board is formed to protect the fisheries ?—To protect the fisheries, yes.

32098. And you suggest those Fishery Boards ought to have ample power to stop these pollutions ?—If the pollutions are sufficiently serious to warrant it.

32099. Does not the question come in as to the relative value of the industries which cause these pollutions, and the value of the fisheries ?—I think it does, but, of course, in our district the mines started are simply small things started by a few speculators as a rule. I do not refer to Mr. Bayldon's Mine, but to those for which £2,000 or £3,000 is subscribed in London. Down they come, they do a lot of damage, and they are gone again.

32100. But the County Council has certain powers if they choose to exercise them ?—I think their powers are very limited, and I do not think they can take action without the consent of the Local Government Board.

32101. (*Mr. Willis.*) That is so ?—Yes.

32102. (*Chairman.*) Have they made any attempt, as far as you know, to stop the pollution from these mining sources, say at Newton ?—No, sir. I think nothing has been done there at all.

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32103. Then your Board has not applied to the County Council to assist them at all ?—No. I am afraid we generally try a policy of bluff. People do not know how limited our powers are. All we can do is to bluff, and then stop if they will not meet us.

32104. Your Board does not seem to have done all that it could do in not having applied to the County Council to take action in this matter under their powers ?—Well, I am afraid we have taken the view that it would not be much use, sir.

32105. Mr. Rowell, what do you wish to add to what has been said by Mr. Michelmore ?—(*Mr. Rowell.*) Shall I read you this very short statement ? This refers to the River Lemon, a tributary to the Teign.

32106. Very well ?—For the past thirty years I have resided in close proximity to this stream, and up to the year 1905, the water has always been quite free and clean except in times of heavy rains. I am personally interested to the extent that I own land for about three-quarters of a mile on the river, which land I let, and is so let at the present time for dairying purposes. I also rent the fishing for about one mile. This river has for a great many years been noted for its trout fishing. In April, 1905, I made complaint to the water bailiff of the foul condition of the water, in consequence of which he visited some mines which were being restarted about 7 miles from the estuary, after being inactive for a period of thirty-five years. On June 2nd, 1905, I picked up several dead trout, the water at the time being of a greenish yellow colour. Samples of these fish were taken (and others subsequently), to Messrs. Hacker and Michelmore of the Teign Fishery Board, were sent for analysis, and found to have been destroyed by arsenical poisoning. This pollution has continued at intervals of a few weeks since 1905, the whole of the fish being destroyed. On February 25th, 1909, the owner of the mines in question re-stocked a portion of the river with trout, these, however, were also destroyed later. From March 27th to May, 1910, the water was continuously in a very bad condition, fish being destroyed at the estuary. On May 3rd, 1910, at the request of Messrs. Vicary and Sons, I went with their representatives Mr. Brock, and Mr. Tickle an analyst, to the mines, and samples of water were taken. Although on each occasion the mines have been visited the water flowing from the adit has been found to be clear, there is little reason to doubt but what at times it must be in a very foul condition, the bed of the stream and stones are thickly covered with a brown deposit, a moorland stream joining it immediately below the mine being perfectly clear and pure. There has been no authenticated case of cattle being injured; the owners remark that the cattle will not drink the water, and when the river is polluted they have to place their stock elsewhere to be watered. Practically the whole of the land adjoining the river is meadow land, and is let by the various owners for grazing purposes. It is, therefore, most essential that the water should be quite pure, as formerly, and we consider we are entitled to have it so. I have the reports of analysis of dead fish by Dr. Wynter Blyth, dated May 25th and June 1st, 1905, and of Professor T. E. Thorpe, dated 9th June, 1905, also a report of a visit to the mines on September 8th, 1905, by Messrs. Bathishill and Houlditch (solicitors to Mr. Bayldon), Dr. Masterman, Mr. C. E. Fryer and H. G. Michelmore of the Teign Fishery Board.

32107. (*Sir William Ramsay.*) Is the presence of arsenic shown in the fish ?—Yes.

32108. What was the nature of the mine to which you referred ? Is it a lead mine or a tin mine ?—Tin and arsenic. I have a Report by Dr. Wynter Blyth and Professor T. E. Thorpe.

32109. They both say that arsenic is the cause of death ?—Yes.

32110. (*Chairman.*) You say the whole of the land is meadow land, and is let by the various owners for grazing purposes ?—Yes.

32111. Has there been any reduction in the letting value in consequence of what you complain of ?—I cannot say that is so. The owners are rather afraid of what may happen at any time, and they are quite willing to make affidavits to support my statement, that they think it should be remedied.

32112. What is the nature of the loss that you yourself have sustained ?—Well, I have lost, from a sporting point of view, my fishing to begin with. That is not a very serious matter, but still it should not be.

32113. (*Sir William Ramsay.*) But if you chose to let your fishing, would you get anything for it ?—I could not let it, because there is nothing there to let. There is not a live fish in the river.

32114. What was its letting value ?—Well, about £10 I should say, my own particular stretch. I rent a piece as well; another mile.

32115. (*Mr. Willis.*) What do you pay for the mile you rent ?—£5; that is higher up.

32116. It is no good now ?—Oh, no, there is not a fish in the river at all.

32117. Would it be worth more than £5 if it were good ?—Yes, if there were more fish. I rent it from a relative, and I get it for a corresponding price.

32118. (*Chairman.*) The agricultural loss has not been serious ?—I cannot say it has been. I have cattle myself; I always move them when the water is in this state, because they will not touch it.

32119. (*Sir William Ramsay.*) It is a potential danger, because the cattle might drink arsenically poisoned water?—If they should happen to drink it, they might share the same fate as the fish.

32120. (*Chairman.*) I asked you if it had affected the agricultural letting value of the land ?—It has not up to the present.

32121. (*Sir William Ramsay.*) Is it not the case that it takes a considerable time to be found out ?—The owners do not like to say anything, because if they make a remark they are afraid the letting powers will be lessened.

32122. (*Chairman.*) Have you taken any action of any kind to try and get this pollution reduced ?—Mr. Bayldon the owner of the mine, re-stocked the river, but he will not admit he caused the poison, except on one occasion. I have complained to him personally.

32123. Have you applied to the County Council to put into action their powers ?—No; all I did was to complain to Mr. Michelmore. Of course, he has acted for me practically.

32124. (*Mr. Willis.*) Are you Clerk to the County Council also ?—(*Mr. Michelmore.*) No, my father is.

32125. I thought it was some relation.—Yes.

32126. (*Chairman.*) We thank you both for the evidence you have given us.

Mr. WILLIS BUND, Chairman of the Worcester County Council, called in; and Examined.

Sir WILLIAM RAMSAY (*in the Chair*).

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32127. (*Colonel Harding*). I think we have not received any *précis* ?—No, I was not able to prepare one; I must apologise.

32128. (*Chairman.*) Whom do you appear for ?—I am appearing in consequence of your letter to the Severn Fishery Board asking for some information with regard to the mine pollutions in the Upper Severn; I am their Chairman.

32129. Is there a Conservancy Board of the Severn ?—Yes. Under the Salmon Fishery Acts it has been in existence for forty odd years, since 1866.

32130. Do you find that this Fishery Board has powers ?—No, we have got very limited powers indeed, and that was one of the points I rather wished to press upon you. I did not quite know from your letter what precise points you wished me to direct my

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evidence to. It was rather as regards the mining pollution alone.

32131. You wish to speak about that ?—That is what I understood.

32132. Not necessarily; any pollution which bears upon the deterioration of the river ?—Oh, I am obliged to you. First, of all, it you will allow me, I will speak about the mine pollutions. When we began work forty years ago, there was a number of mines. It was just during the time of the Carlist War when the Spanish Lead Mines were closed or were not working and consequently lead was at a very high price and every bit of lead that could be worked was worked, and a very considerable number, I should think very nearly thirty mines were at work on the Upper Severn. You may take all these as being either in Montgomeryshire or in Denbighshire. The most celebrated of them was a mine belonging to Lady Londonderry near Llanidloes, called The Van. That was a mine, where I believe—I have no knowledge of mineralogy, so I am very possibly making a mistake—the lead was found in pockets. They hit upon a very large pocket of almost pure lead, and the shares in that mine—I had one or two—were £4 10s. paid and they sold for £86. Until the pocket was worked out, they paid very handsome dividends. I cannot tell you what the composition in that mine was, but there was some form of zinc which was excessively poisonous.

32133. For cattle or for human beings ?—For everything. It poisoned cattle, it poisoned fish, but I do not think anybody drank the water. While the pocket lasted, the mine was very prosperous. And the workings were very considerable, so much so that they constructed a railway from the Cambrian Railway up the valley to the mine. When the pocket was worked out, the mine went into liquidation. I am bound to say, when they were prosperous, they did everything they could to help us and to minimise the pollution as far as possible, and on the whole they succeeded.

32134. Might I interpose a question ? Did the pollution consist of sediment or dissolved matter ?—It consisted of both. Unfortunately, there was a great deal of sediment, but there was some form of zinc in solution. We summoned the Mining Company for killing some fish. The water was beautifully clear, but we summoned them. The fish all died, the Company were convicted, and they appealed to Quarter Sessions. We had the advice of the County Analyst and I thought that we ought to get some further evidence to support him at the Sessions, and I went to a celebrated expert and told him what I wanted. He said: "What do you say it is ?" and I told him I had written down it was this particular form of zinc. He said: "I can be of no use to you." I said: "Why ?" "That form of zinc is not soluble in water." That put one in rather an awkward position. But whatever form of zinc it was, it was soluble in water and it was very poisonous. They got one or two Companies to take over this great mine, but they had not money to work it and had not money to look after it. And the curious thing is that we never again came across any soluble poison; it is all now in suspension.

32135. That is a tributary of the Severn, I presume ?—It is on a brook called the Cyerst Brook which runs down into the Severn. It is between Llanidloes and Caerens.

32136. Is most of that deposited in that brook, or is it carried down into the Severn ?—No; they have very large settling pits. They made them in the days of their prosperity and the great difficulty is to make them keep these settling pits clear and also to regulate the supply of water into them. They seem to think anything will do for a settling pit; as long as there is water running into it it does not matter, and that has been one of our great difficulties to get them to regulate the water, to keep the pits cleaned out and see that too much water does not go in.

32137. These mines are still working ?—Yes. Then, I want to tell you our second difficulty, because it is rather a remarkable one. They polluted the river very badly. As you see, the sediment came down the brook right into the Severn, and from the point of junction with the Severn for some way down, following the line of Cambrian Railway, almost down to Newtown, everything was killed. This deposit got on the bed of the river and it killed not only the fish, but it killed all the fish life; whatever fish were there were starved; everything was killed. Curiously enough, it improved the fishing above the mouth of the brook amazingly. Unfortunately, in the Severn, there are a great many coarse fish, chub, pike, dace and so on, and they get up into the water where the trout are and spoil the fishing to a considerable extent. They could not pass or did not pass this polluted zone, consequently the trout had it to themselves, and from the mouth of the brook, up to the source of the Severn almost, the trout fishing improved amazingly and really became very first-rate and it still is the best trout fishing on the Severn. Of course, no salmon ever got up to show their faces there.

32138. No ?—Well, that Company failed and another Company came and the Fishery Board, by working at them in one way or the other, were able to get them to keep the pollution down and now the working is comparatively small, I think very little harm is done. Occasionally an accident happens, a settling pit bursts, and then, of course, there is damage, but taking it all through, I do not think there is a very large amount of complaint, because one cannot help accidents and you cannot help sometimes a heavy storm coming or, a man has not cleaned out the settling pits in their right order, something of that kind; but as a rule the thing works pretty well. Then, passing from the Van, the success of the Van made all the other places where they could see lead start working it. That was the great danger we had. They had no money, except what they could get to start a mine near the Van, on the same range, and, of course, all those places do more or less pollute and we suffer a good deal from that. Naturally they come to grief in the course of the first two or three years, but they do incalculable harm in that time.

32139. By beginning mining and turning out stuff that will not settle ?—Turning out stuff that will not settle and very often poisonous stuff as well and saying: "We shall put in settling pits if the thing pays." It goes all into the river and then goes on to the spawning beds, and either prevents the fish spawning, or in some cases kills the fish. That has been the case in several instances. Well then, at the present time, we have only two other mines at work besides the Van. The Van is on the Severn, on this brook which goes into the Severn, the other two are just in Denbighshire. They are at the top of a river called the Tanat, which comes into the Severn lower down. One is at a place called Llanrhaideren Mochnark, and it is rather a good example of a mine which does an immense amount of damage, and I do not quite see how the damage is to be got over. The mine is three parts of the way up a very steep hill. There they drive from the face of the hill straight in, they bring out a whole lot of stuff and have a mill where they grind and treat it. About half-way down the hill, they have what they call some settling pits, very much too small and much too shallow and the water to them is not regulated. In the case of a storm, it comes down and washes them all out and does far more harm than good. But the great point with regard to it is this, that from the position every thing is washed right down into the stream. There is no flat ground at the bottom, at the foot of the hill, and for a long way down the stream the whole of the spawning beds and bed of the stream is covered with the debris from this mine. With every wish to make them do something, I really cannot suggest what they should do, because from the configuration of the ground one cannot say: "You cannot work your mine," and so there is a very great difficulty in that way. It is through it being out on the side of a hill. If there was flat ground at the bottom, to which they could bring all the refuse, we could do something, but there is not and it seems unreasonable to ask them to take it perhaps a mile farther down, to make a tramway to treat it there. It would kill the mine; they would not have the money to do it. That is one of those cases where I do not see my way to do anything.

32140. Would you place any comparative value on the fisheries and on the mines ?—I know the fisheries are let to a club for about £30 a year, and the mine has changed hands, I think it is four times, in the last two years, so it is not very valuable.

32141. Are there many people employed at the mines ?—No, about six or eight, I should think.

32142. Quite a small number ?—Quite a small number, but still it does the mischief, you see, because just as soon as ever a heavy storm comes all the mischief is done.

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32143. What remedy is possible?—Has the Fishery Board power to prosecute the mines?—We have got the power in all cases where the stuff put into the river sickens or kills fish. We have to prove that the fish are sickened or killed.

32144. Can that be done?—In some cases it can. We have been successful in certain cases, but it requires very great care and constant watching. But, in this case, no, because I cannot say that the debris here does either sicken or kill the fish. It simply destroys the spawning beds. That is why we want some remedy as regards that. And in this particular case, I really cannot suggest anything. There is a third mine that is now at work on the other side, the same range of hills as that one I have been speaking of, at a place called Llangynog, which is also in Denbighshire, and which is somewhat similar except that they have utilised a bit of flat ground about half-way down the hill for their works, and their works occupy so much of the ground that there is very little room for the settling pits, and they say the adjacent landowners ask them so much money for rent for land for more settling pits that it is impossible for them to afford to pay it. That is a case where I think something might be done. The Board should have compulsory power of acquirement, the rent being left to arbitration. And looking at the value here it is a case of land for agricultural purposes—which is the only value it would have—and it would not be worth 5s. an acre. They want £3 or £4 for it for settling tanks.

32145. Is that all the damage that has been done from mines?—At the present moment, lead mining does not pay for the reason that the price is so low, the carriage is so difficult to get the lead away, so that is the only damage we have now. We have had a great deal, but that is all the damage we have now from lead mines.

32146. There is no smelting carried on there?—No. The most serious thing we have now is a rather curious matter. It arises from a totally different thing. As you are aware, the City of Liverpool has constructed enormous waterworks on a tributary of the Severn. We call it Lake Vrynivy, and from that lake they carry their water to Liverpool. They have got very large filters for these works, and they clear out their filters near Oswestry on a stream, a tributary of the Severn, called the Modfa. The slime from the filters comes out in very considerable quantities and there are great complaints about it. It cakes over the bed of the river just in the same way as you put a layer of cement. The Liverpool people say they have a right to clear out their filters; they do as little harm as possible.

32147. Must they put that stuff into the river?—They clear it out, and it gets washed into the river.

32148. It is very putrescible, I believe?—Yes. I came away in a great hurry this morning and left my papers, but I have got an analysis of that which the Board of Agriculture have made for us, which I will be very glad to forward you, to attach to my evidence, to show what was the composition of this stuff.

32149. Does it smell?—I do not think so, but it spoils the river by overlaying the bed.

32150. That destroys fish-life too; it prevents spawning?—It prevents spawning, and, what is worse, it prevents food. It kills all the small insects so that there is practically no food for the fish and they starve. I do not believe that the fish are so much killed off directly by pollution, except it is very strong pollution, as they are starved for want of food. That is what kills them.

32151. Then, as regards sewage pollution, are you troubled with that at all?—Yes, but not so very much. Perhaps I had better begin and go down the river. The first place we come to is Llanidloes. At Llanidloes there is a good deal of pollution of a very nasty description from the flannel works. They treat it, they take it into their sewage farm and treat it with ordinary sewage. Except that they make the ordinary sewage appear and smell much nastier than usual, I do not know that there is very much gained by it. But I am bound to say that, as a rule, unless the water is very low and something has happened to it, the effluent, it is fairly good. I should not like to complain of it, except at times.

32152. Is there any other process used there except the farm?—No; I think it is only the farm; I think it is only broad irrigation. Well, the same thing, but to probably a larger extent takes place at Newtown. There, Messrs. Price Jones have very large flannel works. The District Council are supposed to intercept all the sewage, take it to a sewage farm, treat it by broad irrigation and then, having done that, there is a pipe goes down to the river and the effluent is discharged. We get complaints at times that solids are placed in the river. At times certainly fish are killed, but they say it is only when a tank has been cleared out or an old standing tank leaks or something of that kind. I cannot say it is injurious as a rule; it is only injurious at times.

32153. Have you noticed sewage fungus in the stream, a sort of white substance?—No, I do not think so; I never heard of that being on any stream there; there is a very large amount of water.

32154. And relatively a small amount of sewage?—And relatively a comparatively small amount of sewage. The same applies to the next place, Welshpool. There was a proposal to start preparing skins for kid gloves, but the poison they proposed to use—some form of arsenic—was so very deleterious, that we got the Town Council to interfere and that was stopped. Then, we get on to Shrewsbury, and Shrewsbury treat their sewage. They have got some bacteriological tanks. They divert it all from the river, they treat it all, and they put it in again; there are very considerable complaints, but I do not think, from the fish point of view, there is very much harm done. Then there is a long length all through Shropshire where there is certainly a good deal of injury in a way. All the towns round Ironbridge and from Ironbridge downwards, almost to Bewdley, are just on the banks of the river, and they all drain into the river. There seems to be no collection or diversion of the sewage, but, as a rule, it is house sewage, and unless the water is very low, I do not think very much harm is done. At Bewdley, at times, there is some harm from some tan yards. There are some tan yards there, and the lime from the tan pits, if it is dealt with carelessly, does certainly cause damage. Then, just below, at Stourport, they get the Stour, which comes down from Kidderminster, comes in, and there again at times the fish are killed wholesale. That is when some of the Kidderminster people clean out their vats, or let the refuse go in that the Town Council will not take to the sewage farm. It is very poisonous, there is no doubt about it, but it happens once in a couple of years, something of that kind; it is not a permanent thing. Well, then we get to Worcester, and Worcester is in a very unfortunate position as regards sewage. They spent £80,000 some years ago in turning it into the river, and now they are spending over £100,000 in trying to get it out, but they have not been successful. They and the Local Government Board are in continual litigation with regard to it. I do not like to say anything in regard to it. I do not think there is any actual damage done at the present moment. They have got a large sewage farm and tanks and all sorts of things, but they will not work or they work very badly for the simple reason that they cannot get the sewage there.

32155. Has it to be pumped?—No; it is a gravitation scheme by which it has to pass under the river by a syphon, and the syphon is always getting clogged or doing what it ought not to do. There is a screen on the other side, but the syphon is not delivering the sewage properly. Either it passes too much or too little, and it will not work, and they are continually at loggerheads with the Local Government Board about it.

32156. When it does not work, is there an overflow?—No; I think it then goes through the old sewers.

32157. Straight into the river?—Straight into the river. But I cannot say very much about that, because it really does not do the fish any harm, I think, at present. They have spent so much money that one does not like to say anything further in regard to it. Then there is nothing until you come down to the tide-way, till you come to Gloucester, and at Gloucester they are carrying out now a new set of sewage works. They are taking the whole of the sewage and discharging it, I believe, altogether untreated into the tidal part of the river. I do not think the works are finished. They are taking it there by a syphon under the river, and they are going to discharge it just below the weir below the city at Llanthony Weir, and what I am afraid of is this, that at low water on the discharge of this sewer there, the sewage will be just

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washed about and the high tide will bring it back again; it will all keep there, and it will never get clear away. They say it will not, but I think that is the danger there.

32158. Does your jurisdiction extend into the tide-way? —Oh, yes, right down to the Bristol Avon.

32159. As regards powers, have you any suggestions to make in which you would ask for increased powers, or any arrangement by which a Rivers Board would be created, not merely to deal with fish, but to deal with any pollution of the river?—That is what there ought to be. There ought to be a Rivers Conservancy Board dealing with all these matters. It is absurd one dealing with fish and another Board dealing with the means to prevent injury to fish.

32160. Is water taken from the Severn for drinking purposes?—Oh, yes; Worcester is supplied from it.

32161. Are the water works interfered with by the pollution of the river?—There is about 12 miles and a very large volume of water, and it is very highly filtered. People say that it is unhealthy, but I should not like to say. I drink the water myself, so I should not like to say.

32162. Are there any other points you wish to bring before us?—I do not think there is anything I can usefully occupy your time with; these are the main points. Of course, I have taken it simply on the ground of fish, you understand, and not as regards in any way the public health point of view. I ought perhaps to have said, when you get into the tide-way, there is very often very great complaint, whether right or not, I think there is a good deal in it, that if the sewage comes in at Gloucester, and Gloucester sewage is not pure sewage, mixed manufactures and sewage, if fish are coming up, a shoal of salmon are coming up, and they meet with this coming down, they at once go back to the sea and will not run up again, and one of the great complaints of the upper people is that that is the reason they do not get the fish. That is more as regards distribution than injury. I never knew a fish killed by it, but I do think very likely it does give the fisheries, say from Newnham down to the Avon mouth, more fish than they otherwise would get, simply because the salmon will not face the matter coming down.

32163. They stay down below?—They stay down below. I ought perhaps also to say, it may perhaps be of interest, the Worcestershire County Council some years ago now, tried some bacteriological tests on the different forms of sewage in their area. They wanted to try to see which was the best process to recommend, and they tried some at Malvern. We got the leave of the Council there to try these experiments and what we found was this, that the process that gives the purest effluent was not the best for the fish. The purest effluent does not necessarily have the most oxygen—I think that was the result we came to—and that the fish will live longer in a worse effluent with more oxgyen than in a very pure effluent with less. That was the conclusion we came to. We tried it in a place in the north of the country, Oldbury, where there are large chemical and other manufactories. We tried bacteriological filters there, and they were an utter failure. The mixed combination that came from the works, the sewage and the refuse, made them so. And the same, to some small extent, at Kidderminster. They were always liable to be made useless. They would work very well for a fortnight or so, and then would become useless. That was the conclusion we came to. We did not carry out our experiment further from rather an unfortunate occurrence. We were told, at least I was told, I should be prosecuted for carrying out experiments on living animals without having a licence, so they came to an abrupt termination. But one did find this that if you can be sure of getting your effluent sufficiently oxygenated, it does not really matter so much for the fish that the effluent does not come up to a fixed standard of purity.

32164. Has there been any action by riparian owners against the polluters of the river?—I do not think by riparian owners. There has been by District Councils in one or two cases under the Rivers Pollution Act, but then they have delayed a long time and nothing effectual really has ever come. There have been several by District Councils against manufacturers. We have had also—this is not from the fish, but from the County Council point of view—several rather important points to deal with on the Stour. There was a large system of deep drainage laid in, and in one part of the district there are large galvanising works, and the effect of the galvanising works on the drainage pipes, large iron pipes, gave rise to some very difficult and troublesome questions.

32165. But that, of course, had nothing to do with the pollution of the river exactly?—No, except that the pollution was discharged into the river.

32166. Have you any suggestions to make, as regards the alteration of the law, besides the suggestion that the whole river should be put under a Rivers Board, dealing with the whole of it?—I think there should be some authority, I do not care what, but some independent authority who should have power when once there is pollution to apply to the County Court. I cannot say what body.

32167. It has been suggested that a Central Board, with its seat here, in London, should be appointed, who could hear appeals of this sort, or who could receive complaints? —I want some body to be able to make an Order to stop the pollution at once until the question is decided as to it. If you could get such an Order as the Chancery Division would give at a reasonable cost it would meet the case.

32168. You go to the Chancery Division at great expense?—And meanwhile you do not get the thing stopped. You want something to stop it at once. As regards the County Court, the difficulty is the procedure, with two months' notice of the action; you want something very short and summary. As regards the magistrates, I do not want to say anything against local magistrates, but a great many of them are the polluters, at any rate they are not completely independent. It must be a Central Board, it must act quickly; it must be an independent authority.

32169. We are very much obliged to you for the evidence you have put before us?—If I may, I will send the Secretary the analysis and you will see at once.

32170. Thank you very much.

Mr. **Edward Joicey**, called in; and Examined.

Mr. Edward Joicey.

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32171. (*Chairman.*) Have you sent in any *précis* of your evidence?—I simply wrote a letter. I did not know at all what information you wanted; whether it was simply to deal with sewage or general pollution, and I take it the Commission is only dealing with the South Tyne. That is all I can speak of.

32172. Might I ask, what do you represent?—I am the Convener or Chairman of the South Tyne Fishery Board—the Committee rather—the South Tyne Committee of the Tyne Salmon Conservancy Board.

32173. (*Sir William Power.*) How far eastward on the Tyne does that extend?—Westward from Hexham to the source of the South Tyne, which is up in the Cumberland Hills beyond Alston.

32174. (*Chairman.*) You were to speak about the South Tyne.—Yes, do you wish to hear about the whole of the river?

32175. I think we might.—It is seriously polluted, not with sewage so much, but mainly from collieries, and in two cases there are lead works.

32176. You heard Mr. Willis Bund's evidence?—I did.

32177. I suppose yours would be of the same sort?—Yes, somewhat of the same sort.

32178. I think it would be valuable to have the details.—I will give it as well as I can, but I cannot give exactly the history of the pollution. I can give you a certain amount of information on the subject.

32179. Would you kindly tell us what you know.—In the first place, if you take the South Tyne as joining the North Tyne at Hexham, a few miles up, about 4 or 5 miles up, there is a certain place called Fourstones, and here there is a little runner comes in which is very badly polluted from some lead or zinc works there—old lead

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works—and I believe they are working pyrites there, and they wash this stuff, and the result is it comes down a milky white colour and of course pollutes the river to a certain extent.

32180. It is not a poison; it is quite insoluble in water?—I do not think there have been any cases of fish being poisoned from that. Then, the next pollution is higher up again—I think the Blacket Colliery—which is merely yellow water pumped into the river from the workings. I do not think it does any harm to fish.

32181. Is that their coal washing?—No, simply mine water pumped out. The same takes place again at Haltwhistle. There again there is the South Tyne Colliery, which is being pumped, and the water is yellow; it is oxide of iron. Then, there is a little burn comes in above that—just above Haltwhistle station—which is called the Tippalt Burn, which is very seriously polluted. I am afraid I am partly responsible; I have property up there. Part of the pollution is from an old mine; that we cannot help. The water comes out by gravitation; it is a horrible water very highly charged with oxide of iron, and it comes into the burn. Well, above that, a few miles higher up again, is a new Colliery—the Thirwell Colliery—which is quite a small colliery that has been working now for about two years. I do not think it pays. There has been a strike there for a year in consequence of some dispute between the masters and the men, and I know it is a very difficult pit to work. It is quite on a small scale, but they are polluting the Tippalt Burn very seriously, not only from the pumping operations that are going on, but principally from a siding they have put up, which is made of material from the sinking, and which I suppose is what is called brass.

32182. Arsenical Pyrites probably. Pyrites anyhow.—Yes, and whenever there is rain it comes off this heap a bright yellow.

32183. Do you happen to know if the water is acid there?—I do not know. I have had it analysed when it reaches the burn and is diluted with burn water, and the result of the analysis was that it was not very poisonous. I myself was inclined to take action, but I was advised that I had not sufficient to go on as I had no evidence that fish had been poisoned by it. Now that the water has been low for a very long time, we notice the stones are all coated, and the result of course must be that insect life is destroyed, and I should think it would be very harmful to spawn. It coats the spawn over with a brown scum.

32184. A brown coating?—Yes. Then, I ought to say that this company have diverted a little runner up there from the watersheds of the Irthing into the Pow Churney Burn which runs into the Tippalt. This runner is polluted by a railway embankment formed by the Thirlwell Colliery Company. I saw the Manager some months ago—six months ago—and I pointed this out to him, and he had the runner put back into its proper course, but since then it has been again diverted into Pow Churney Burn. That is all I have to say about that part. Then, higher up again, opposite Featherstone Castle, 3 miles higher up the Tyne, there is a pollution from a pit. The Hartley Burn is polluted by a pit and a coal-washer, and the water comes down quite black with coal dust. I do not believe there is a single fish alive in Hartley Burn.

32185. Does the coal-washing reach the Tyne?—Only in flood time. The Tyne there is very clear at present. I saw it a few days ago, and it is very clear indeed. Then, the most serious pollution of the South Tyne is some 10 miles higher up, where the Nent joins the South Tyne. It is a considerable stream, quite a river, and for a very long time there have been extensive lead workings at Nenthead. Recently a foreign company have taken it. I believe I am right, I am not quite sure, but within the last few years a foreign Company have taken it.

32186. A Belgian Company?—I believe it is, and they are polluting the river very seriously.

32187. They are mining zinc, I think?—Yes. Well, at the Fishery Board, at our last meeting a month ago, there was a complaint from a riparian owner on the Nent, saying it was doing his cattle a great deal of harm, and he hoped the Fishery Board would take some steps to prevent this pollution. We sent our inspector up to look at it, and he reported that he had been very carefully over the whole system of settling tanks, and that they were putting in a very elaborate system; and we thought, as we had nothing to go on in the shape of dead fish—that we could only let the thing rest until we had a further report from him as to whether the tanks were sufficient for the purpose.

32188. You do not happen to know whether they turn out soluble impurity?—As far as I remember, he had consulted some fishermen up there—men who were trout fishers—and what they said was that there were absolutely no fish in the Nent at all, and they attributed that partly to the poison, and partly to the fact that there is absolutely no spawning ground left, because the washing is always moving and filling up the spawning beds.

32189. That is near the source, I think?—That is near the source.

32190. Then, as regards sewage pollution, have you anything to say about that?—Well, of course, villages do pollute the river to a certain extent.

32191. Do you look upon that as seriously deleterious to the fish?—I do not think so; I think the fish generally thrive on a little sewage.

32192. They get something to eat from the sewage?—Of course, it is very offensive.

32193. Is the total value of the fisheries on the Tyne and its tributaries very great?—No.

32194. Are the fishing rights sold, or do the proprietors keep them?—The proprietors keep them. There are one or two angling associations, and they of course are very keen on having the river kept as clean as possible.

32195. Do the proprietors often let these fishings?—They are not let except with other sporting rights.

32195*. If they are destroyed, does it lower the letting value of their property?—Yes, certainly. We always look upon it as a second-rate salmon river, but we think it could be made into a good salmon river if these pollutions were done away with. A large number of salmon run up South Tyne as far as Warden Dam which they cannot negotiate. There is a fish pass on the North side which is not in the main streams, so that fish do not use it, as they might do if it were better placed. The result is that fish after lying below the dam fall back and go up North Tyne.

32196. Do you complain of the state of the law, or rather of the amount of evidence required in order to start a prosecution?—Do you find, as other witnesses have told us, that you require actually to prove the death of the fish?—That we have always found. We have had several cases of actual poisoning, but we have had very little to go on because we have not been able to produce the fish. One hears cases of fish being found dead, but we are not always able to substantiate that. The fish must be analysed to prove whether it has died as the result of poison.

32197. You would regard the damage as principally done by the destruction of the spawning beds?—I think that is the principal damage.

32198. (*Mr. Willis*). You have no power at all as regards the spawning beds?—I take it that the Fishery Boards have no power at all.

32199. You have only power if there is an actual fish? Yes.

32200. (*Chairman.*) So that the river might be destroyed for fishing purposes, or there might be destruction of the spawning beds, and nothing could be done to remedy it through the Fishery Board?—That is so. I think the fishing is very seriously injured by these new colliery workings. I think it is quite possible to filter that water to a sufficient extent, so that it does not foul the River and tributaries and I think that when railway embankments are made they should be constructed of proper material, and not of anything that is likely in wet weather to poison the water. That is a point that I do not know has ever been mentioned before, but we have a railway running alongside the river Tyne for many miles, and I have noticed often that red water comes out from the railway embankment being polluted by the material of which the embankment is constructed.

32201. It would be rather expensive to purify the river from iron. It could be done by filtering it through limestone; that is a question to be considered?—Yes.

32202. (*Mr. Willis.*) You consider that is due to the material of which railway embankments are formed?—In places where there have been collieries, and in places where there are old pit heaps, it is impossible to get over the difficulty.

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32203. (*Chairman*). Is there anything further you wish to say?—I do not think so.

32204. Thank you very much for coming before us.

ONE HUNDRED AND FIRST DAY.

Wednesday, 14th June, 1911.

PRESENT:

Sir William Ramsay, K.C.B., F.R.S. (*in the Chair*).
Colonel T. W. Harding, J.P., D.L.
Sir William H. Power, K.C.B., F.R.S.
Mr. F. J. Willis.
Mr. R. H. H. Keenlyside (*Secretary*).

ALSO PRESENT:

Dr. George McGowan.
Mr. C. C. Frye.
Mr. G. B. Kershaw.

Mr. George Jewel Lister Ellis, Clerk to the Camel Board of Conservators, called in; and Examined.

Mr. George Jewel Lister Ellis.

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32205. (*Chairman.*) You are a solicitor residing at Wadebridge?—I am, Sir.

32206. And you are Clerk to the Camel Board of Conservators?—I am.

32207. Would you care to amplify this statement which we have here, or would you prefer to read it?—I think I would prefer to read it.

32208. If you will read it, we can put some questions to you afterwards?—I have known the district in which I reside for the past twenty-five years and upwards, and am conversant with the sources of pollution in the watershed on the River Camel. During my term of clerkship with the said Board of Conservators my duties have frequently taken me to the mines which discharge polluted water into the River Camel. All the sources of pollution are on the left bank; the principal is the Ruthern Tin Mine on a tributary about 2 miles from the tideway. This is a large works employing until recently about fifty head of stamps of the latest pattern, the motive power being steam and water crushing approximately 100 tons a day. The mine is not at present in work, but it is understood that a new company is being formed to take it over. The tailings from the old and new works are being worked and the waste flows into the river at Grogley Bridge. Another mine is being opened on the same stream nearer Grogley halt, but at present is not sufficiently developed to be any material cause of pollution. A third mine is situated at West Downs in the parish of Lanivet, and the pollution from it empties into the River Camel by a small tributary at Nanstallan. There are two sets of stamps in use of sixteen head each with another set temporarily idle from want of water, and the average crushing is approximately from 50 to 60 tons per week with sixteen hands. But with a slight increase in the winter. Practically no measures are taken to allow subsidence. There are two or three catchpits, but they are all very small and are evidently rarely emptied, although there is plenty of space to enable the adventurers to provide others, and the water after passing through the Stamps is discharged with mud and sand into the river, the bed of which is coated with a thick slime in which it is impossible that fish can spawn for a distance of 4 or 5 miles. Large quantities of mine silt are also deposited along the banks which are brought down by the winter floods and impede navigation in the Estuary. At Dunmere there is a considerable source of pollution proceeding from the sewage outfall of the county town of Bodmin. Traces of the pollution can at times be seen as far as half a mile down the river, and the stench is distinctly noticeable from the opposite bank. The effluent from the sewage works passes through a dairy farm after entering the river from which the cattle daily drink. Samples have been taken and are provided. A large field of china clay is being operated by the North Cornwall China Company in Crowdy Marsh in the parish of Advent, which is viewed with considerable alarm. Extensive dries have been erected at Pawleys Bridge, the clay being conveyed in pipes by gravitation from the pits on the marsh a distance of 7 miles; the present output is estimated from 30,000 to 40,000 tons per annum, and it is at times more especially during the winter when there are heavy surface washings that considerable quantities of mica, etc., find their way into the river and discolour it for miles, and choke the spawning bed of both salmon and trout, on the occasion of my last visit, viz., on June 6th last, large settling pits had been made and were in course of construction, but in my opinion the walls built of turf are too thin and are not given batter enough on the outside face to resist the pressure when filled. At that date there was a quantity of mica, apparently unnecessarily, escaping into the river which immediately above was quite clear. In my opinion it should be possible to bring pressure to bear on individuals to prevent injury resulting from carelessness or from neglecting to take ordinary precautions against possible injury by the discharge of polluting matter. Another China Clay Company is working at Blisland and Greenborough; the dries are at Tresarrett; the contamination from this source which was very bad a few years since has greatly improved and is now very slight.

32209. I would like to ask a question or two as regards that summary. Could you tell us the length of the Camel approximately?—Including its windings, I should think about 25 miles.

32210. And does this pollution refer to the lower part of the Camel or the upper part?—The clay works refer to the upper part, and the mines refer to the lower part.

32211. Has it been up till now a great fishing river? It has been a good salmon spawning river, but the salmon run very late in the year, and consequently they cannot be caught; they run after the time that is allowed by the Act to take them.

32212. Could you put a value upon the fisheries?—No, I am afraid I could not.

32213. Is there salmon caught at the mouth of the river at all?—Yes, there are about six licenses taken a year at £2 each, and there are other licenses further down the coast on smaller rivers.

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32214. Tributaries ?—Not tributaries of the Camel, but they are under the same Board of Conservators.

32215. Are there riparian proprietors who let their fishing ?—Yes, there is one who lets his fishing; I think only one.

32216. The others retain theirs ?—No, they do not retain them. They allow the public to use them by permission. They are not particular; they do not issue cards. They make nothing out of it.

32217. You spoke of two sets of stamps in use of 16 heads each. Does that refer to all the mines ?—No, sir, that is one mine.

32218. That is the third mine ?—That is at Lanivet, West Downs.

32219. How long has this state of the river existed ?—You say " the bed of the river is coated with a thick slime in which it is impossible that fish can spawn for a distance of 4 or 5 miles." Has that been the case for long ?—Oh, yes, a number of years.

32220. Many years ?—Yes, before I knew the river.

32221. So that there is nothing new so far as that is concerned ?—Nothing new, except the sewage.

32222. We will talk about that afterwards. What was the result of getting samples from this river ?—You state that samples were taken. Were they found to be poisonous ?—They are here, sir. They are before you. (*Samples exhibited.*) This is a sample showing a considerable sediment if you work it up. This is the state of the water as it leaves the mine; that is the state of the water immediately above it. These were both taken last week.

32223. Do you believe that they contain poisonous matter ?—I think not; it is tin. I believe there is very little poison in tin.

32224. There is not much lead there ?—There is not much lead there; very littte lead. It is a low grade of tin; they produce about 4 lbs. to the ton of ore.

32225. You say that cattle drink the water. Does it do them any harm ?—There have been no visible effects so far, but presumably it is rather bad for the milk. I am not speaking now of this sample; I am speaking of their drinking the sewage, not drinking the mine water. I do not think the mine water would hurt them.

32226. Is there no purification carried out at Dunmere for the sewage of the town ?—Yes, they have the usual septic tank system, but either through want of regulation by the Town Surveyor or otherwise it is inefficiently constructed. I do not know of course, what the cause is, but you will observe from this sample that it is in a very bad state indeed.

32227. Does the river bear a very large proportion to the outfall of the sewers ?—Oh, yes.

32228. Very many times its volume ?—Oh, yes, many times.

32229. There is a word I do not understand in the last sentence of your statement " dries." Does that mean the dry refuse ?—Of course, the clay is separated from the mica by washing, and the washing of the clay is very much the same as that, only it would be like lime wash; it would be white. When it is settled, the settlement of that water is the clay. Then that is taken down to the ovens or " dries " where the railway sidings are, and there it is dried, so that they can cut it down in squares and pack it.

32230. That is what is called " dries " ? It is really a sort of oven.

32231. Do you know why the contamination from this China Clay Company at Blisland has so greatly diminished ?—I think they have provided catch pits, which formerly they had not done.

32232. So that it shows it is possible to prevent contamination of the river ?—Oh, yes, it is quite possible.

32233. (*Colonel Harding*): You tell us that the Ruthern tin mine deals approximately with 100 tons a day ?—Yes, sir, when it is in full work.

32234. Of that 100 tons, what proportion would be washed into the river ?—The whole of it.

32235. Surely they withdrew something ?—Well, they withdraw the ore of course—the separation of the ore—but as far as the tailings are concerned, it all goes into the river.

32236. The bulk of that 100 tons would go into the river daily ?—Yes.

32237. (*Chairman*): There is only about 4 lbs. per ton ? Three and a half to 4 lbs. for every ton of ore crushed. It is a very low grade of ore.

32238. (*Colonel Harding*): Is that mine, as far as you know, a prosperous concern ?—No, I think not at present. Of course, it depends very greatly on the fluctuating price of tin.

32239. Do you know the value of the shares ?—No, I do not. It is under reconstruction I believe at the present moment.

32240. How many people are employed at the mine ? I am afraid I cannot remember.

32241. Fifty ?—No, I should think not so many.

32242. You spoke about the sewage of Bodmin. Is there any treatment of it ?—I believe the usual treatment by septic tanks. They have recently had a new system put in.

32243. Then in regard to the china clay works you spoke about, they are dealing with 30,000 or 40,000 tons per annum. Is also the great bulk of that washed into the river ?—Oh, no.

32244. How much ?—Very little of it goes into the river at the present moment. They save that by a system of catch pits, which are banks built of turf in which the water is allowed to settle, and after settlement it flows into the river. As long as those banks are retained, they are effective.

32245. Well now, do you find that your powers as a Fishery Board are sufficient to enable you to bring pressure upon these mine owners ?—Oh, dear, no! We have no powers.

32246. You have no powers ?—We have no powers, unless we can show destruction of fish by poison, which of course is impossible.

32247. Your showing, for instance, that the spawning grounds were prejudiced by the deposit—— ?—On the lower part of the river ?

32248 . . . would not be sufficient to enable you to take action ?—Only on the lower part of the river; only for two miles.

32249. Would not that be sufficient to enable you to take action ?—I do not think so personally. I have not gone into the question, but if it were we are in such a financial position that we could not possibly undertake any litigation in the matter. We have only about £100 a year to maintain our staff of bailiffs.

32250. You could take action if you proved fish are killed ?—It is very difficult to prove. If you find a dead fish in the river, it is almost impossible to prove how the fish died.

32251. Practically do you find that the results of these various pollutions are serious ?—I do not think they are serious at the present moment, but I think they may become serious.

32252. (*Mr. Willis.*) Have you ever brought the matter before the County Council ?—Not during the term of my clerkship.

32253. How long has that been ?—Seven years I think; seven or eight years.

32254. You know there is an Act called the Rivers Pollution Prevention Act ?—Yes.

32255. And also that the County Council have power to enforce that Act ?—I know that in my neighbouring Conservancy, the Fowey, they endeavoured to enforce that Act, but the County Council would not take it up. I think it was chiefly on that ground that our Board thought it was worthless to bring it before them.

32256. Without incurring material expense, you could bring the facts to the notice of the County Council, could you not, that there is this pollution going on, and ask them to exercise their powers ?—They would not do it in the Fowey, which is the next river.

32257. Well, at any rate there is a way provided by which a public Authority can, at the expense of the rates, take action ?—Well, I do not know what the powers of that Act are, but I take it from you that that is so.

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32258. Under the Local Government Act of 1888, County Councils were established, and one of their powers was to enforce the Rivers Pollution Prevention Act ?—Yes.

32259. And there is provision in Part III. as to manufacturing and mining pollutions, which at any rate on paper seems to be fairly adequate ?—Yes.

32260. I certainly think you might try ?—I can assure you the reason the Board did not try was that an effort was made by the other neighbouring Board, and it was no use whatever, although it was a much more serious case, because it was copper pollution, and that is poisonous to everything which touches it.

32261. The County Council might be more willing to move if they had repeated applications ? That is the way with most public bodies. They put one application on the shelf, but if they get a good many they feel they must do something.

32262. (*Chairman.*) Would you say the members of the County Council are interested in the mines personally ?—No, I do not think so; not to my knowledge.

32263. (*Sir William Power.*) The water that is used in the mine operations; is that taken from the river commonly, or from a private source of supply ?—Oh, it is taken from the tributaries of the river Camel itself.

32264. Then they are under an obligation to return an equivalent amount of water to the river. You can look after that, I suppose as conservators, can you not ?—I suppose they are; but the less they return of this (sample produced) the better.

32265. And it should be in a proper state ?—Yes.

32266. But have you not attacked them on that ground ?—No, we have tackled them on the ground of providing catch pits to prevent this pollution. We have repeatedly interviewed them on that question.

32267. And you have always made your representations directly to them, and not through the County Council ?—Yes.

32268. (*Chairman.*) Is there anything further you would like to add to your evidence ?—I think not, Sir. I think I have given you all I know about the matter.

32269. We are very much obliged to you ?—Thank you.

Mr. William Edward Raine, called in; and Examined.

Mr. William Edward Raine.

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32270. (*Chairman.*) You have given us a short note of your evidence. Would you care to read that or a longer statement ?—I have a longer statement which gives it in detail. That only gives it in mere outline. I have also the maps; would you like to see them ?

32271. I think we have a map; the Ordnance Survey ?—All the streams are coloured on this one.

32272. If you will kindly read your longer statement, perhaps we may be able to put some questions to you afterwards on the subject ?—Yes. I am a solicitor, of Sunderland, and Clerk to the Board of Conservators for the Wear Fishery District. The District was formed in the year 1879, and it comprises the River Wear and its tributaries within the County of Durham and a portion of the Sea Coast. The river rises in the Pennine Hills and enters the sea at Sunderland after a course of 65 miles. It has numerous tributaries, some of considerable size, the principal being the Gaunless which joins it near Bishop Auckland, and the Browney and the Deerness which themselves join and enter the main river at Croxdale not far from the City of Durham. In addition to these there are a great number of smaller streams entering the river and its tributaries. The greatest difficulty with which the Board of Conservators have to contend is the pollution of the river. Almost everywhere in the district there are carried on industries of one kind or another from which the waters are polluted. In the Durham and Bishop Auckland districts, pollution is more or less continuous. In other places occasional pollution occurs. The principal sources of pollution are as follows: Quarries, lead mines, coal mines, coke ovens, chemical works, gas works, sewerage works. As I understand that evidence has already been given on the subject of coal washing waters and discharges from coke-ovens (I presume coke-ovens of the old fashioned kind, making coke only) I shall limit myself to the questions of the new bye-product ovens and the chemical works attached to them, and pollutions from quarries and leadworks, etc. The pollution from the new bye-product works now attached to many of the collieries, has proved a most serious difficulty to the Board. Formerly, in the manufacturing of coke the production of coke was the main thing considered, but now by the new methods employed, other valuable marketable commodities are obtained besides coke, viz.; tar, pitch, sulphate of ammonia, napthaline, benzol, and oils of various other kinds, and the waters discharged from these factories have proved most destructive to the Fisheries. As an instance of this, I may refer to the effect it has had on the River Deerness. Until six years ago that stream was considered an excellent fishing stream and it contained large numbers of fish in every part of it. In June, 1905, when chemical works had been established at Sleetburn Colliery, a large quantity of a poisonous effluent was discharged from the works into the stream and immense numbers of dead fish were found for a considerable distance below the colliery. Again, in December, 1906, a similar pollution took place with equally disastrous results, and I understand that no fish can now live in the water below Sleetburn Colliery, as the pollution has continued more or less ever since. After the pollution of December, 1906, the Board caused an analysis to be made of a sample of the water and I produce the analyst's certificate.

32273. Might I look at it ?—Yes. (*Analyst's certificate handed in.*)

County Analyst's Office,
Darlington.
November 12th, 1907.

I hereby certify that I have analysed a sample of water from the River Deerness, which was left with me on November 2nd, by Bailiff Rutherford of the Wear Fishery District, and that I find the following results:—

The sample was yellow and turbid. Its odour was offensive.

A chemical analysis gave as follows:—

		Grains per gallon.
Chlorine as chlorides	=	27·30
Ammonia	=	9·81
Albumenoid ammonia	=	·21
Oxygen absorption	=	5·91
Total saline matter	=	132·30
Suspended organic matter	=	·61
Suspended mineral matter	=	2·79
Neutral coal tar oils	=	·21
Coal tar acids	=	·84

The sample is largely polluted with sewage matter, and is also contaminated with substances derived from the distillation of coal. I have no hesitation in saying that the sample would be poisonous to fish.

(*Signed*) W. F. Keating Stock, F.G.S., F.I.G.
(*Durham County Analyst, Analytical Chemist and Assayer, Consulting Chemist.*)

W. E. Raine, Esq.
Clerk to the Wear Fishery District,
Sunderland.

I visited the place on Tuesday the 6th inst. I found that the water from the vicinities of the coke ovens, ammonia house, benzol house and another house where they wash and grind a substance called "Baryta" were all being turned into the stream. The effluent entering the stream was quite hot, and it gave off a vapour, a breath of which caused a choking sensation. There were also traces of tar on the surface, and the bed of the stream was thickly coated with tar in some places. The water from the benzol house was discharged in the first place into a trench about 9 inches wide. Its temperature would be almost boiling point and it was noticeable that the grass for about a foot on either side of the trench was completely destroyed. I understand that above the colliery there are still fish in the Deerness. What I have described may be taken as an example of what goes on at many of the collieries in the district, except as regards the Baryta, which I believe is only worked at Sleetburn. On the same

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day I visited the Dean and Chapter Colliery, Ferryhill, which belongs to Messrs. Bolckow, Vaughan & Co., Ltd. They have a similar plant there for the manufacture of chemicals, and they also manufacture sulphuric acid. They have, however, a system of settling ponds and filtering beds, and the water, when discharged into the neighbouring Beck, though clear of any deposit had something of a slaty colour. At the Weardale Steel, Coal and Coke Company's Colliery at Spennymoor they also have chemical works, the water from which is discharged into a stream called the Valley Burn, which flows along one side of a somewhat busy thoroughfare. The water on the 6th inst when I was there was quite hot, of a very dark, slaty colour, and it gave off a similar vapour to that at the works previously visited. There were also traces of tar in the water, and the bed of the stream was thickly coated with tar. I was informed that the smell from the stream becomes so offensive at times as to render it almost impossible for people to pass along the street. I understand that some two years ago a horse and two cows were poisoned through drinking the water in this Beck in some fields through which it flows not far from the colliery. On Thursday, June 8th, I visited Auckland Park and Eldon Collieries, at each of which there are chemical works similar to those I have already referred to. The former belong to Messrs. Bolckow, Vaughan & Co., Ltd., and the latter to Messrs, Pease & Partners, Ltd. The water from these collieries is discharged into the Gaunless. At Eldon Colliery there did not appear to be anything to complain of, the mischief having been remedied, I understand, by the water being now pumped on to the top of a fiery heap and allowed to percolate through it. At Auckland Park Colliery things did not appear to be quite so satisfactory, though I am assured by Mr. Hare, the manager with whom I have been in correspondence for two years, that the works for preventing pollution will shortly be completed. On Friday, the 9th inst., I visited the Broken Back Colliery, St. Helens, which belongs to Messrs. Pease & Partners, Ltd. The water from the chemical works there is collected into a pond at the foot of the pit heap on the north side of the railway, and it is passed through a pipe under the railway, across a field and into the River Gaunless, but there are no filtration arrangements except a hole with some lime in it in the field on the south side of the railway. The water was of a dark brown colour. On the same day I visited the Randolph Colliery, Evenwood. There, the water, which is also of a dark brown colour, is turned into a large pond on the top of the refuse heap from one corner of which it flows in the same condition as when it enters the pond, through a pipe on to the side of the heap and into a stream emptying itself into the Gaunless. These chemical pollutions extend over what may be described as the middle portion of the river. The poisonous liquids enter the tributaries in the first place, and the surface of the water becomes covered with froth which collects and forms a thick scum. At Durham City, where the water runs somewhat slowly, this scum may be seen in large patches, and I understand from the water bailiff that no fish are to be found near such places. Before leaving the subject of chemical pollutions I may mention a serious, though fortunately exceptional, case which took place in March last year when 1,200 gallons of creosote were discharged from the Bankfoot Colliery, Crook, into the Beechburn or Crook Beck. This appears to have been due to an accident but it had most serious consequences, thousands of fish were destroyed and the effects of the pollution were seen for several miles, even below Bishop Auckland. I saw the manager at this colliery on Thursday, the 8th inst., and he showed me their new arrangements for disposing of the water. That from the chemical works is now being run into a disused shaft, but the cooling-water from the coke and the sludge from the boilers are still being run into the Beck, and carry with them a thick deposit. The manager said he had no doubt that the company would be willing to provide settling ponds to remedy this if asked to do so, but he did not think any serious injury was being done. Except for a pollution that occurred last Friday, this concludes that part of the evidence dealing with chemical pollutions. This pollution to which I refer was only reported to me on Monday, and it seems the gas company at Wolsingham have decided upon making some repairs to the gasometer, and for that purpose on Friday last they commenced to pump out the water under the gasometer. They were warned, I understand, by the Police Sergeant that to do this and let it flow into the river would have a serious effect. But notwithstanding that they did commence pumping operations, and they poisoned some of the fish for a few hundred yards. When they saw the effect of it they stopped further pumping operations, and I understand they are now digging trenches into which to turn the water before turning it into the river. Someone in that part of the district has informed me that if they had gone on putting this water from their gasometer into the river, if they had put the whole of it in, they might have poisoned everything down as far as Sunderland. What I have said applies only to the non-tidal waters of the river. I had no time to visit the other parts of the river. The only other place that I think it would have been of any importance to go to would have been the chemical works at Washington. There they have extensive chemical works, but as this is the tidal portion of the river, and as I had no time to go there, I have no evidence on this at all. The next part of my evidence applies to the pollution from lead works. In his Official Report for the year 1878, the late Mr. Frank Buckland said of the Wear: "The great cause of the scarcity of fish in this river is without doubt the 'hush' coming down from the lead mines in the upper waters. . . . The water, besides being poisoned by the refuse of the lead ore, is also contaminated by the refuse of the mines being tipped into the river, whereby also the spawning grounds are seriously affected." The state of affairs described by Mr. Buckland has now almost disappeared, and serious pollution from lead works seldom takes place. There are fewer lead mines worked than formerly, and the methods of working are much improved. I visited the Sedling Mine near the source of the river on Thursday last, the 8th inst., and saw the washing operations in progress. The spar is placed in the washer and after a few minutes the particles of lead are gathered up and the spar, instead of being turned into the river as in Mr. Buckland's time is put to one side to dry, it being now a valuable marketable commodity. I understand it is used in blast furnaces. Nothing is carried into the river from the washer except, perhaps, a small quantity of soil. Although the water was very low last week, it was practically clear of pollution. Some trout were to be seen a few yards below the works. For want of time I was unable to visit any other lead works, but I had with me a member of the Board who resides at Westgate, and also two water bailiffs, and I was given to understand that, in a general way, nothing worse goes on at the other lead works. The mines are worked chiefly by the Weardale Lead Company, Ltd., of London. There has, however, been one serious case of pollution from the lead works recently. This happened in August, 1910, when the fish in the Killhope Burn and the water for two miles below were poisoned by a discharge from the Sedling Lead Mines, Cowshill. I understand it was due to the miners having accidently cut into some old workings and freed some water which it is supposed must have been there for many years, and this water being pumped out of the mine caused the pollution referred to. Except in this instance, no very serious case of lead poisoning has taken place in recent years. In the early part of last year the Board complained to the company about the discharging of injurious effluents from the Rookhope and Stanhope Dene Lead Mines and the Wolf's Cleugh Smelting Works, but the matter was speedily attended to. *Pollution by Refuse from Quarries, etc.*—In November last the Board had occasion to complain to the owners of some Whinstone Quarries at Cowshill as to their placing refuse from the quarries into the Killhope Burn, so that it might be carried away by floods. By this means it seems, the owners of the quarries had got rid of some hundreds of tons of refuse. Notwithstanding the Board's complaint the practise was not discontinued until quite recently, and there now remains a large heap which will be carried away with the next flood. I visited the place on Thursday the 8th inst., when it was explained that they had no other means of getting rid of the surface soil, and they did not think any harm was being done. I produce a photograph of the place which shows it practically in its present condition. (*Photograph handed in.*)

32274. (*Colonel Harding.*) Is the stream alongside the wall ?—Yes, Sir. The stream is behind that heap, and the only channel it can possibly have is down by the wall. They informed me that they had removed all the surface soil that they had any occasion to deal with at present, and for a long time to come there would not be any more pollution of the sort after that heap had been taken away. In conclusion I may refer to a somewhat similar kind of pollution with which the Board have had to deal on more than one occasion recently, viz.:—the tipping of refuse on the river side by Local Authorities. The Durham City Corporation have for a considerable time had a tip of this sort below Durham in a bend of the river, and the refuse deposited there cannot fail to be washed into the river when floods occur. Both the Board and the County Council have complained of this for a long time, and I understand that a retaining wall is shortly to be built to remove the causes of complaint. There was a similar case at Page Bank near Willington some three or four years ago, but the Water Bailiff informs me that a wall has been erected. That is the whole of my evidence.

32275. (*Chairman.*) Was the Wear formerly known as a very valuable fishing river ?—I believe it was in olden times.

32276. Is it within your recollection that it has been ?—Not within my recollection. I may say that it abounds with bull trout in the autumn months, and sea trout also ascend it, and occasionally salmon, but it is a very long time since I think it was famous as a salmon river.

32277. Have there been fishing rights on the banks of the river ?—There are riparian owners, of course, almost from Lambton Park, the Earl of Durham's residence, right up to the source of the river—the riparian owners everywhere.

32278. Have they complained that they have been deprived of their rights by the fouling of the river ?—I have never heard any complaints.

32279. There have been no actions by the riparian owners on the river ?—I do not remember any in my time.

32280. Then, beginning at the top, I presume the lead mines are well up the river ?—Yes, Sir, the lead mines I think begin at Stanhope. Beginning at the top, they begin at Cowshill near Killhope Burn, the Sedling Lead Mines to which I refer in my evidence, and they come down as far as Stanhope on either side of the river. I could show it exactly on the map.

32281. But you say the pollution from lead mines has practically ceased ?—Continuous pollution has ceased; it is only occasionally now that we have any need to complain about pollution from lead mines at all.

32282. You spoke of spar. Is that fluor spar ?—Yes.

32283. It is used in blast furnaces ?—Yes, it is used in the steel blast furnaces.

32284. (*Sir William Power.*) The lead mining has gone down a great deal ? There are not nearly so many engaged in it ?—I understand there are not so many lead mines worked now as formerly, but still the lead work in Weardale is an important industry.

32285. And is it likely to revive, do you think ?—Yes, I think it is doing fairly well. These Weardale Lead Works have their head office in Lombard Street, London, and I think they are a very good Company.

32286. (*Chairman.*) Is any smelting carried out there, or merely ore extraction ?—There is not very much smelting, but we complained last year about pollution from the Wolfs Cleugh smelting works. They are on the North side of the stream a little above Stanhope; I think they are shown upon that map, but there is no smelting carried on at this Sedling Mine which I have referred to.

32287. There is pollution when smelting is carried on, is there not ?—Yes, Sir, I believe there is sometimes. We complained last year about pollution from these smelting works, and we had some samples of the water taken. One sample was clear, pretty much the same as that, (*indicating a bottle standing on the table, which had been previously handed in by another witness*) and the other contained a substance, like shellac, in suspension.

32288. Do you know what it was ?—I do not know what it was. We complained about it, and they took steps to remedy it.

32289. So there appears to be no difficulty in remedying the trouble ?—When a pollution takes place, and as soon as we complain, they appear to be very willing to take steps to put a stop to it, but these chance pollutions coming without any warning do incalculable harm to the fisheries; occasional pollutions which of course we do not hear of for a day or two, and the mischief is done by the time we hear of them.

32290. Then, passing further down the river, you have a number of coke ovens and collieries ?—Yes, Sir.

32291. And that I think is the most serious cause of pollution ?—Yes, the most serious pollution that we have to deal with at the present time, and it practically prevents the fish from getting about the river; it keeps them locked up in these higher reaches practically; the river trout, brown trout.

32292. You spoke of chemical works. Are they at the mouth of the river ?—There are some chemical works at Washington. They are worked by a large Company called the Washington Chemical Company. I believe they have their headquarters at Newcastle. They are about 8 miles from the mouth of the river on the North side.

32293. (*Sir William Power.*) Where it is tidal ?—Yes, Sir, it is tidal up there.

32294. (*Chairman*). Do you know what they make ?—I don't know; I think they make gases, the gas they use in lanterns.

32295. Naptha ?—The gas I refer to is in cylinders. I had not the time to make inquiries, or I should have been prepared with evidence upon that. I can say that seven years ago there was an Inquiry. The Durham County Council applied to the Local Government Board to have that portion of the river down as far as Barmston declared a stream within the Rivers Pollution Act of 1876. This application was heard at Washington, and the various local authorities opposed it, and all this was inquired into then . . . the question of these chemical works and the sewage from Chester-le-Street and other districts round about, and I understand that notwithstanding this attempt on the part of the County Council the Local Government Board decided against the application, so that it still remains tidal waters, and outside the provisions of the Rivers Pollution Prevention Act. I could not work it up in the short time I had; I could not make inquiries as to whether any serious pollution takes place. In former times we had occasion to complain. They keep some very large heaps outside their works a short distance from the river. These heaps resembl lime. They can be seen from the railway in passing, and I understand when a heavy rainfall comes, something injurious may be washed into the river; but it being tidal, and the flow of the river being very swift from there to the mouth, I do not think it is looked upon as a very serious difficulty.

32296. Were there old alkali works there which had been abandoned ?—I think so.

32297. They are probably alkali heaps ?—Yes, I think so.

32298. Then as regards the coke ovens and coal mines, I suppose they pollute the river considerably, although they work up their coal ?—Yes, Sir.

32299. Is there no purification attempted there ?—Well, purification is attempted at some places. At the Sleetburn Colliery they tell us they pass the water from the coke ovens . . . ; at least, they did tell us so when this last pollution took place . . . , into the fiery heap and allowed it to percolate through the heap. Last week when I was there it did not appear to be percolating through it, but going over the side of the heap like a waterfall. It was joined by the water from the Baryta house; that was a milky colour. It was also joined by the other water, the hot liquid I spoke of as coming from the benzol house; that was clear, but rather resembling paraffin in appearance and colour. All those waters mingled together, and at a bridge a few hundred feet below the colliery they enter the River Deerness, and I understand they render it absoltely useless as a fishing stream, and kill everything below there.

32300. Does the volume of the effluent bear a large proportion to the volume of the river ?—I should say it would bear a very large proportion to it last week when the river was low, and the stream from which it comes will be perhaps 9 feet wide, and that running into a stream a very little wider, it must be injurious I think at all times.

32301. That is to say, the actual stream of effluent is about 9 feet wide ?—Yes, coming from the colliery; wider sometimes.

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32302. And the river itself is what ?—The river will vary. Last week it was very low and very narrow, but at times it will get to great width, a big pool in fact, just below where this enters it.

32303. But could you not give some sort of guess as to the width of the river where it enters ? Is it 20 feet ?—It will go to 20 feet when there is much water in the river.

32304. Do you know if this stream is contaminated at particular reaches, or is it contaminated all the way down ?—I understand above the colliery it has not been affected; only from the colliery downwards has it been affected by this pollution. It joins the Browney, and it forms a common stream and then flows into the main river.

32305. In to the Wear ?—Yes.

32306. Which is a large river at that place ?—It is a large river at that place about Durham; for a considerable distance it is a large river; somewhat large.

32307. You have referred to sewage pollution. Is there much sewage pollution ?—There is a good deal of sewage pollution. In fact, by referring to the analyst's certificate, you will see he says there that the water is contaminated with sewage pollution.

32308. Do you happen to know if the villages or towns on the banks purify their sewage ?—They do at some places. I know at Durham they have filtration works there. I do not think there is much to complain of there about the water entering the river. The County Council look very sharply after these local authorities now. Then we had to complain about the sewage at the Crook Beck recently; we have had complaints about that. They have a sewage farm there, and a few weeks ago the pipes got choked up. The result was the overflow went into this Crook Beck, and could not fail to do damage. At other places there are sewage works, but they are well looked after by the County Health Inspector. Sewage is a serious sort of pollution. They happen to let it off sometimes I think rather more freely than should be done, and the result is that the crude sewage gets into the river at times.

32309. As regards the Conservancy Board what do you consider your position with regard to this river; to attempt to reinstate the fisheries, or to keep the river reasonably pure ?—Well, to reinstate the fisheries by keeping the river pure.

32310. Do you find that you have sufficient powers to do that ? For instance, to whom do you make representations ?—I usually receive notice of these pollutions from the water bailiff or the police, or from any other source. I immediately communicate with those who are responsible for the pollution, and they say they will put a stop to it perhaps, and we usually get something from them to re-stock the river; but the Board would much prefer that these pollutions should be put a stop to, and the river would re-stock itself then.

32311. Do you find them willing to meet you in every case ?—They are very willing to meet us in almost every case. Sometimes they are very obstinate. They sometimes deny that it comes from their place at all, but they are frequently willing to meet us in the way of giving £10 or £20 towards the re-stocking of the river when we ask them to do so. The only alternative of course is that Sec 5 should be put into operation, Sec. 5 of the Fisheries Act, 1861, but that is an extremely difficult section to work; and as far as I know the Wear Fishery Board have never attempted to put it into operation.

32312. Do you find that the spawning grounds are interfered with ? Have you been apprised of that ?—The spawning grounds, I understand, are interfered with by such pollutions as that from the Cowshill quarries.

32313. (*Colonel Harding.*) That is right at the head of the stream ?—Yes, Sir, right up at the head of the stream pollutions of that sort, and any pollution which puts a kind of solid pollution into the stream. Coming to the lower reaches, the Browney and the Deerness for instance, if these pollutions could be put a stop to, the fish in those higher waters would be able to get about the stream, and have access to and from the main river, and also the autumn fish coming up would be able to ascend into those streams. I understand they are excellent streams if only they could be opened out, but they are practically closed by these pollutions.

32314. (*Chairman*). I think you said that no action had been taken by riparian owners ?—I have never heard of a case of litigation by riparian owners. We have a great many riparian owners on the Board of Conservators of course, and they look to the Board for dealing with these matters.

32315. (*Colonel Harding*). You spoke about the difficulty that arose in connection with the quarries at the head of the stream ?—Yes.

32316. Are you able to prove actual damage to the fisheries from the deposit of matter washed away from those quarry heaps ?—I am afraid we could not prove actual damage. I understand if it came down in sufficient quantities into a small burn, it might do actual damage, but it is a great difficulty with us to prove actual damage.

32317. What is the damage which you think arises from that source ?—We think that if a solid substance of that sort gets into a stream and thickens the water, it not only silts up the gravel, the bed of the stream, but it also kills the fish by getting into their gills. This thick deposit gets into their gills and suffocates them.

32318. Are there not ample powers to prevent the casting of solid matter into the streams, which could be exercised, if not by you, by the County Council ?—We always complain to the County Council in cases like that, and they do what they can, but they invariably tell us their powers are limited to the question of the public health; that they can only exercise the provisions of the Rivers Pollution Act, 1876, where the public health is concerned.

32319. (*Mr. Willis*). That is their policy, or do they say that is the law ?—That is the law, I understand, the Rivers Pollution Act, 1876, is what they go upon.

32320. There is nothing about that in the Act. Do you know the Act ?—Yes, I know the Act.

32321. (*Colonel Harding*). Do you suggest that persons may cast barrows-full or carts-full of ashes into the river, and, provided there is no injury to health, you cannot prevent it ?—Only so far as I know under Sec. 5 of the Salmon Fisheries Act, 1861. We have power under that to prosecute anybody, and the penalty is £5; but if they show they have done all they can within reasonable cost to render the substance harmless, then we are unable to get a conviction.

32322. Under Sect. 5 of the Act of 1876 it is laid down that: "Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any solid matter from any mine in such quantities as to prejudicially interfere with its due flow" and so on, can be prevented from doing so ?—Yes.

32323. You would have to show that it interfered with the due flow. I suppose it is not suggested that it does. Does it ?—No, I am afraid we could not prove that, because it would be washed down the stream. The stream runs tolerably fast, and I do not think we could prove that. We might prove that in connection with these quarries at Wearhead.

32324. Could you prove that in connection with these quarries ?—Yes, Sir.

32325. Does it interfere with the flow; does it cause silting up of the stream ?—Yes, Sir, it has stemmed up the stream behind it; it practically stemmed it up, as that photograph shows.

32326. If you are able to prove that, why does not your Board take action under that section of the Act of 1876 ?—Well, I have had it before them two or three times, and they instructed me to write to the owners of the quarry, and I have done so. At the last meeting I was instructed to complain to the owners of the quarry, and they replied to the effect that they would meet us as far as possible.

32327. There is Sec. 2 of Part I. of the Act of 1876, which says: "Every person who puts or causes to be put or to fall or knowingly permits to be put or to fall or be carried into any stream so as to either singly or in combination with other similar acts of the same or any other person interfere with its due flow or to pollute its waters the solid refuse of any manufactory manufacturing process or quarry or any rubbish or cinders or any other wastes or any putrid solid matter shall be deemed to have committed an offence against this Act." It would seem as if it ought not to be difficult for your Board to take action.

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32328. (*Mr. Willis*). The County Council could take action.

32329. (*Colonel Harding*). Your Board or the County Council ?—The County Council have of course complained about the other.

32330. Does your Board call the attention of the County Council to these matters ?—Yes, they do frequently.

32331. And the County Council take no action ?—Well, their inspector may go and complain, but they frequently point out to us that they see to the public health, though they do help the Fishery Board very considerably.

32332. Could you not call their attention to the sections which I have read to you ?—Yes, Sir, I could do that. I could easily do that ; Sec. 2 and Sec. 5.

32333. I have only one other question to ask you in regard to the lower or tidal portion of the river, in regard to which you told us you had not had time to get up evidence ?—Yes.

32334. Do you happen to know the Washington Chemical Works ? These are old soda works, I think, which are no longer working, but were there not large waste heaps on the banks of the river from those works ?—Yes, there are huge heaps.

32335. Do you happen to know if the rain washes down from these heaps objectionable matter into the stream, and there is considerable pollution from these heaps ?—Yes ; some years ago the water bailiff reported upon that, and I complained to the company, and they said they would do what they could.

32336. Is the company working ?—Yes, it still works.

32337. Are those heaps being added to ?—I could not say that.

32338. But you have noticed the pollution which is washed into the river from those heaps ?—Yes, Sir ; the water bailiff has.

32339. Is it serious ?—Well, it may not be so serious in the tidal portion of the river. It would be better if it were not there, I think.

32340. (*Chairman.*) Is there anything you would like to add to what you have stated ?—I do not think there is anything I need add, Sir.

32341. We are much obliged to you for coming to give evidence.

Mr. T. MEDLAND STOCKER and Mr. CLAUDE MARTIN, called in ; and Examined.

Mr. T. Medland Stocker and Mr. Claude Martin.

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32342. (*Chairman.*) You have sent in, Mr. Stocker, a statement ; would you care to amplify it, or would you care to read it ?—(*Mr. Stocker.*) Just as you like.

32343. Perhaps you had better read it and we can get it on our notes, and we can ask you some questions on it afterwards ?—Yes. Shall I read it ?

32344. You represent the China Clay Association, I think ?—The China Clay Association, yes ; for the Cornwall St. Austell District.

32345. Are you proprietors ?—We are workers ; we hold our works on a Royalty license.

32346. Are you the manager ?—I am the manager of one of the largest clay works in Cornwall. The china clay industry consists of the removal of the soil or overburthen and the preparation by washing of the kaolin.

The kaolin or china clay is apparently disintegrated granite. A stream of water is conveyed over the kaolin ground which has been previously broken by hand. The action of the water conveys the gravel and the kaolin in suspension to the bottom of the clay mine. The gravel and sand are separated from the clay in suspension by large receiving pits which are alternately emptied. The sand thus trapped is conveyed by a tram line to the top of the clay mine and deposited in a rubbish heap. The proportion of gravel or sand varies considerably in the different pits, but approximately from 5 tons to 8 tons of gravel and sand are thus dealt with for each ton of clay extracted. A very large portion of this sand in the early periods until about 1860 was despatched down the rivers, but gradually the practice has prevailed of keeping the sand and gravel on the land adjoining the clay mine. At the present time I believe the various clay works retain the gravel and sand on the mine.

The clay in suspension in the water is conveyed by means of a pump to the surface, the water containing about 3 per cent. in volume of china clay.

The clay consists of the fine china clay which is used in the manufacture of pottery, paper and textile goods, and also the coarse china clay, or, as it is locally termed, mica, the coarser clay or mica being extracted from the running stream by a process of gravitation. This coarse china clay or mica is in the majority of works again subject to a further course of gravitation. The finer particles are used for inferior paper ; the coarse particles are thrown away into the streams or rivers. It is due to these coarse particles that the discolouration of the streams in the neighbourhood of the clay works exists.

The Clay Mines of the St. Austell district produce about 500,000 to 600,000 tons of China Clay annually and the streams or rivers affected are three in number :—

(1) A small stream rising in the Bugle district which flows down the Luxulyan Valley and enters the sea at Par.

(2) A stream which rises :—

(*a*) In the Bodmin Road Valley, near St. Austell.

(*b*) A second stream which joins the same river near St. Austell rising in the Gover Valley.

(*c*) A small stream rising near Burngullow which joins (*a*) and (*b*) at London Apprentice.

This river flows down the Pentewan Valley entering the sea at Pentewan.

(3) The River Fal. This stream flows through the Meledor Valley and is joined at Crow Hill Viaduct by another stream flowing from St. Stephens Coombe, also containing mica.

This is a very considerable difficulty in purifying water containing China Clay. The specific gravity is of such a nature that great difficulty is experienced in clay works in which the rain water is used, and in many cases during the winter months it would be impossible to separate the very fine particles of clay from the water. During the winter season the rain naturally washes the huge banks of clay sand, producing a discolouration which is unavoidable.

The fixing of any standard for the clay streams would be most detrimental to the industry.

The prices obtained for China Clay at the port vary from 12s. a ton to 26s. a ton, and before the producer can obtain any profit the following charges have to be paid :—

(*a*) The removal of the overburthen which varies from 10 to 30 feet in depth.

32347. Might I interrupt to ask what is done with that overburthen ?—It is deposited by the side of the pit on a waste ground, just like large sand heaps of refuse, so the overburthen. It is earth and just the soil underneath the earth for 10 or 12 or 15 feet to 30 feet.

(*a*) The removal of the overburthen which varies from 10 to 30 feet in depth.

(*b*) The erection and maintenance of pumping and winding machinery with the necessary shafts and levels, it being necessary in order that the article may be purified that the water provided shall be at least 97 parts to 3 parts of clay.

(*c*) The erection and maintenance of large tanks and pits for the purpose of settlement and of the drying of China Clay.

(*d*) The Royalty to the landowner.

(*e*) The cost of rail carriage to the port.

(*f*) The labour cost involved in the production.

(*g*) The coal necessary for drying the clay and for the pumping and winding engines.

The margin of profit on this article therefore has necessarily been small and any difficulties which may be raised in reference to the disposal of the mica must be detrimental to the industry. It must be remembered that this refuse is not trade refuse in the ordinary sense of the

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term, but consists of natural mica, which is alumina and silica.

Horses and cattle drink from these clay streams, and it is a well-known fact that horses accustomed to the clay streams prefer them to pure water. The luxuriant vegetation existing on the banks of the streams conveying the clay water show that it is not by any means detrimental to vegetation.

On several of the streams clay companies have been formed for the purpose of dealing with the refuse mica which has been thrown away in the stream, and although naturally this refuse has a very small commercial value, the small companies which have erected drying sheds and settling tanks for this purpose naturally object to any alteration in the present method of dealing with mica.

32348. Would it be convenient, Mr. Martin, if you were to add to this or make any statement ?—(*Mr. Martin.*) Well that covers exactly the working of the China Clay producers in Devon. In the Plymouth district the process is exactly the same, as in the Cornwall District in getting clay, and I do not think I could add to that very well, except in particular reference to our own China Clay Work, in which we have laid out a large piece of land with the view of keeping back any rough portions which might otherwise flow into the river.

32349. From the point of view of preventing the river being silted up ?—Yes. As a matter of fact, some years ago the Admiralty came to us and complained that we were helping to silt up the estuary of the River Plym near Plymouth, and in view of that we had to make some arrangement to keep back the mica and sand from flowing down this river.

32350. What arrangements did you put up ?—We gave over a large piece of land. We are situated in such a way that we can afford to do so. Very few others, I may say, could do so. And on this piece of land we put up, by means of utilising rough clay, a large dam and on this dam all the effluent from the China Clay pits was allowed to flow, and was held in suspension long enough to enable it to settle there. By this means the effluent actually passing into the stream was almost clear except in cases of heavy flood, of course, when it would be impossible to keep it clear.

32351. Did it require a very long standing in the tank before it deposited ?—Oh ! no ; the material is so heavy that it would deposit itself at once when it became still when the actual force of the stream was removed from it ; perhaps a day, or even a few hours, would deposit the rough, what we call the rough mica.

32352. I was going to ask Mr. Stocker if there is plenty of land near his work ?—(*Mr. Stocker.*) In some places ; it depends entirely.

32353. You talk of depositing the rough sand on the land ? The rough sand is easily dealt with, but the clay is conveyed in suspension often for a distance of 2, 3, or 4 miles down to the drying sheds, and there it is treated. In reference to this mica, often at the works there might be land available and it might be possible to deal with it, but often at the dries it would be quite impossible.

32354. It occurred to me that you might conceivably make filters of your sand which would catch the mica very largely ?—We could do that if the drying sheds were at the clay works. It is a question of the carriage of the material. It flows by natural gravitation and not road carriage. In the majority of cases the clay dries are situated on the railway siding.

32355. And your actual clay works are on the river ?—Our actual clay works are on the river, and the drying sheds may be two, three, four, five or six miles away.

32356. And you trust to water carriage ?—We trust to water carriage.

32357. That is done in chutes, I suppose ?—In pipes.

32358. Would it be very difficult to get land near the drying works where you could filter off your deposit ?—It would be very expensive. The clay works are situated generally on waste land. It appears that clay is a very cold material, and in the majority of cases the clay pits are on moorland ; in the large majority of cases.

32359. If subsidiary companies, as you say, can deal with the mica which runs down this stream, surely it would be a very little extension for the main company to deal with it and extract it if it is worth extracting at all ?—They only extract a very small portion ; I do not suppose they would extract more than one in a hundred.

32360. Any attempt to extract more would be commercially a failure ?—It is very cheap mica, worth 12s or 14s., and out of that they have to pay the port dues, the rental of the land and their drying costs. Generally the clay is in a wet condition. After settlement in the tanks, there is generally 50 per cent. of the water remaining and the drying cost would be 3s. per ton on the average at least.

32361. Are you far from the shipping port ?—Varying from 10 or 12 miles to 4 or 5 miles.

32362. Are we dealing with fishing rivers here ; are fish caught in these rivers ?—Not in the Cornwall Rivers.

32363. (*Mr. Willis.*) Is it because of your Clay Works that there are no fish ?—Well, I cannot give you evidence, but I understand this clay has been going down there for about 80 or 100 years. I do not know what existed before. (*Mr. Martin.*) I think probably tin before. (*Mr. Stocker*).—It was a tin river previously ; there is refuse of tin remaining all down the valleys and I think in all probability, the tin was streaming there very much at the same time as the china clay was commencing. I question whether, in any of the three rivers I have mentioned, there would be any fish.

32364. (*Chairman*). Do you know whether any experiments have been made as to settling the clay in the water by adding salt to it ?—Various experiments have been made. You see it would mean a very great difference in the number of settling tanks required. The clay merchant has to provide a dry which will dry about 200 tons of clay a week and he requires a sufficient number of settling tanks. The clay has to remain in the settling tanks for at least two months before the clay is sufficiently settled, before the solution remaining is a solution containing only 50 per cent. of water, and various experiments have been made from time to time but with very little practical result. There is not 1 ton in 100 which is assisted in the settlement by the addition of any material. Of course, the difficulty is in the use of pottery and in the use of china. The manufacturers are very careful it is the natural material which they obtain.

32365. But I am speaking rather, not of the settling of the china clay, but of the settling of the refuse afterwards which is not used, if it were desirable to keep the river clear. I think you could manage to settle your refuse by adding a little salt to the material ?—I do not think so, not materially ; we have tried several things for our own benefit and I do not think we have been successful. The only thing I know which might possibly assist is soap water, but that again would be almost as bad as the article we are making.

32366. Very possibly ?—Yes.

32367. Is your contention that there is no serious damage done to this river ? I presume I ought to ask you, has it at all silted up because of your clay going down ?—We have had no complaints. There are two or three places in which occasionally the river bank breaks. I think the difficulty arises more from the luxuriant vegetation than anything else ; sufficient care is not taken in keeping the river banks clear. After two or three years the river is silted owing to the vegetation growing. In the summer time it is a very small stream and the vegetation naturally grows in the bed of the clay river. All the rivers in the districts in which this clay is produced become very green in the summer time.

32368. Have you any complaints made to you about the state of the river ?—One place is the only place that we get any complaint. I am talking about our own personal works. In one place we get a complaint occasionally. We send a man once every two or three years and he cuts back the vegetation. We do not move any of the material that is deposited.

32369. (*Mr. Willis.*) What is the nature of the complaint that you get ?—The complaint is that the river is filling. We send a man down once in three years, and for three, four or five days he is engaged in cutting down the branches of the trees.

32370. (*Colonel Harding.*) Cutting down the branches of the trees; how would that remove the complaint ?—Because that is the hindrance to the stream; the river-bed has grown together with vegetation.

32371. (*Mr. Willis.*) I suppose you really mean that, although the complaint is made to you, you are not the cause of it ?—We are not the cause of it. If the river-bed were kept clear of vegetation, there would be no complaint of the silting up of the river.

32372. To avoid complaint you cut down the trees and leave your stuff there ?—Yes.

32373. (*Colonel Harding.*) What sort of vegetation is it; weeds ?—Weeds, various bushes and willows.

32374. Do these grow in consequence of islands being formed by the deposit of this material ?—In the summer time it gets into the centre of the stream. It becomes very small in the summer time; it is a very small stream during the summer months, and these banks grow. When the stream rises a little, it creates a settlement; it catches it.

32375. And these deposits, it is alleged, are due to the action of your Company ?—Well, they are due to the vegetation being allowed to form.

32376. But it forms upon these accumulations, does it ?—It forms owing to the vegetation which is grown.

32377. But would the vegetation arise there if it was not for these deposits ?—I think so.

32378. It would ?—I think so.

32379 (*Chairman*). Then, it comes to this, rather, that there are no complaints made and you claim you are not doing any damage to the fish, because there has not been any fishery in your recollection, in man's memory ?—That is so.

32380. And, therefore, that you are carrying on a perfectly harmless undertaking ?—That is so.

32381. (*Colonel Harding.*) The action of these small clay companies, of course, is beneficial to the river, as far as it goes ?—Yes.

32382. But does it pay them to carry on this business ?—Well, they are the very lowest grade of clay merchants and it is the lowest grade of material that they catch. Occasionally they pay, occasionally they do not pay, and occasionally they close. I should say, at the present time, there may be ten or twelve such companies catching the refuse.

32383. They are satisfied with small profits ?—They are satisfied with very small profits; they are small companies.

32384. Is it worth the while of your Company catching this stuff ?—Our Company catch, perhaps, I should think at the present time, about 30,000 tons of this refuse clay ourselves, after washing the clay, and we wash perhaps, 150,000 tons of clay in the year, that is of the fine clay.

32385. Then, these little companies pick up the crumbs that fall from your table ?—They pick up the crumbs after we have had our second innings. We catch this mica.

32386. I see you have been careful to call attention to this, that the margin of profit is small in this industry, and that anything further you are called upon to do might be detrimental ?—It would be detrimental.

32387. Is your Company a public Company ?—Not generally. There are a few public companies.

32388. Is your own Company a public Company ?—I think, legally, we should be termed a public Company. I do not exactly know the Company Law at the present time. I believe when the number of shareholders exceeds a certain number they are a public Company. We are a registered limited liability Company.

32389. Are the quotations of your shares published ?—No.

32390. Would it be an indiscretion to ask you what is the quotation for your shares ?—We have no sale of shares, practically.

32391. I will not press that ?—We have no sale of shares.

32392. (*Mr. Willis.*) Do you represent an Association here to-day ?—I represent the China Clay Association for the Cornwall District.

32393. So you are representing ?—500,000 to 600,000 tons.

32394. (*Colonel Harding.*) You are representing a number of companies ?—I am representing the Cornwall District; I represent five-sixths of the clay trade. Mr. Martin represents Plymouth.

32395. (*Mr. Willis.*) You said just now that they were not damaging the fish, because they had not been there for eighty or a hundred years. You were referring to one specific works, I suppose ?—No, I was referring to these three streams.

32396. And so far as you know, none of the works you represent to-day are situated on streams on which there has been fishing for a great number of years ?—That is so. I believe the three rivers I have quoted deal with ninety-nine one hundredths of the clay production in Cornwall which I represent.

32397. We have had some complaint, I think, that this clay material gets on to spawning beds, and in some cases does damage to fishing ?—I heard, in reference to the River Fowey, that some clay work had been started. The River Fowey is a clear river on which there had never been situated any clay, mica or clay works. I do not know where the work is situated, but I heard of some clay being sent down the river. I have heard of nothing recently. I do not know whether the clay work is still working or not, but the River Fowey is a clear stream; I know the River Fowey.

32398. You are not troubled because all your Works are on streams that have not been fishing streams ?—That is so. I should say the River Fal is a river emptying into the river flowing from Truro to Falmouth, in which I should say there would probably be fish, but exactly what action the clay stream has on the fish in the main river, I do not know. I have never heard any complaint.

32399. What ought to be done in a case like this ?—Supposing you have a fishing river and you are starting a clay works there, and the result is you destroy the fishing. If it is impracticable to do the settlement, what would you say should be done; what would be the right course for a public authority to take then ?—I think it becomes a question, in the public interest, as to the value of the industry as against the value of the fish; how far one would be the predominant interest in the public interest.

32400. (*Chairman.*) Might I interpose a question here What number of workmen do you employ; I mean by the word "you," the whole Federation ?—We are employing about 1,000 men and we are doing about one-fifth of the trade. I should say from 5,000 to 6,000 men.

32401. It is a very considerable industry ?—In Cornwall it is one of the largest industries.

32402. Is there any trouble about the estuaries ? What becomes of this mud which you turn into the river; it must reach the mouth, I suppose it deposits there, does it not ?—(*Mr. Martin.*) It does to a certain extent. It is fine as compared with what you call heavy sand, and gets carried well out to sea in the case of floods which occur periodically.

32403. Is the sea greatly discoloured or whitened ?—Not for any distance; in fact one might say the sea is not discoloured except just at the point where the stream flows into it. (*Mr. Stocker.*) It is very difficult; in reference to that question, at times there is absolutely no discolouration; at other times there is quite a discolouration, and it is quite impossible to give the reason. It is not because of an excess of colouring matter; it appears to be a matter of weather or a reflection of the sky, but at times you can see quite a discolouration, and at other times there is absolutely no discolouration with the same stream flowing. Why it is, I do not know.

32404. Might I suggest to you that when it gets mixed with the salt water, there is no discolouration and it settles quickly ?—It may be. I do not know what it is. It is a peculiar thing. On certain days I have seen quite a discolouration for quite a distance.

32405. At the estuary ?—And on other days there is practically no discolouration at all.

32406. Are there large estuaries on your rivers ?—No, they are small. The first one I was dealing with in the Bugle District enters the sea at Par. It enters the sea at a very short distance from the mouth of the Harbour, *Mr. T. Medland Stocker and Mr. Claude Martin.*

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and there is no difficulty with vessels entering the Harbour. With reference to the second stream, the Pentewan stream, which enters the sea at Pentewan, on that river they have had difficulties at Pentewan in reference to the Harbour, but in order to avoid that, the Harbour Authorities have cut the clay river away from the harbour mouth, a distance perhaps of 600 or 800 yards, which has practically removed the difficulty, I understand. In the third instance, I have no knowledge of any difficulty arising.

32407. (*Colonel Harding.*) Might I ask just one other question? You have told us that on the streams that you are connected with, little or no complaint has been made to you?—That is so.

32408. But you are aware that serious complaints have been made in regard to China Clay Works on other streams?—I am not aware, but I know that a clay work has been started in the neighbourhood of the River Camel. Possibly that is what you are referring to.

32409. May I ask whether your Association includes, and whether you represent, the North Cornwall Clay Company?—No, they are not in the Association.

32410. They are not in your Association?—They are not in our Association, no.

32411. We had evidence yesterday of considerable complaint arising from these works on the Camel, and it was there stated that, for a distance of 7 miles, the present output is estimated at 30,000 or 40,000 tons per annum, and at times, especially during the winter, there are heavy surface washings and considerable quantities of mica find their way into the river and discolour it for miles, and attack the spawning grounds. If that assumption be true, may we take it, that, in your opinion, it is possible largely to remedy that condition of things?—(*Mr. Martin.*) I should say, if they have the ground at their disposal, there certainly is a possibility of being able to keep back a very great proportion of the mica that goes into a river like that. (*Mr. Stocker.*) It depends so much upon the local conditions. I have seen the clay work on two or three occasions; I have not seen the dries; I do not know how they are situated.

32412. But there are means, reasonable and practicable means of settling the mica so as to almost entirely avoid nuisance on the river?—(*Mr. Martin.*) I should say so, if the conditions of the land actually around the works lend themselves to it.

32413. (*Mr. Willis.*) What you want is really a large settling tank for it, I suppose.

32414. (*Chairman.*) Or filter beds?—(*Mr. Stocker.*) Oh, of course it would become a far more expensive way of dealing with this mica to settle it, and probably where you have not got a sufficient area to allow it to remain in one place, when your tank becomes full or your settling bed becomes full, you have to empty it by means of machinery.

32415. (*Mr. Willis.*) It takes a very long time before it settles, does it not?—Before it settles to a condition so thick that you can take it up and remove it.

32416. How long would it have to settle before it got to that condition?—Well, with that material, probably three weeks or perhaps less. In a fortnight you can sometimes handle it very well; it is so stiff you can deal with it.

32417. (*Chairman.*) The storing of the enormous amount of water that you would require is a very serious matter?—You would not actually have to store the water, the mica would settle itself to a sufficient extent at the top of the dam and the water would run off clear in a day.

32418. (*Mr. Willis.*) The top water would run all clear in a day?—Oh, yes.

32419. And you simply leave the sludge at the bottom? —That is speaking of conditions that I know apply at my own works.

32420. At Plymouth, where you have to do it, in consequence of the representations of the Admiralty?—It is possible, if you have the ground at your disposal, but, of course, we had to cover over a very valuable bit of ground for one thing. We absorbed nearly the whole of a farm of 15 or 20 acres, so it is not a thing that everyone can do.

32421. (*Colonel Harding.*) Then, from such settlement as you have just now suggested, the outflow of water would be quite clear, would it not?—Almost clear; it is a little cloudy, but it carries no great volume of heavy matter at all; in fact in fine weather it is drinkable.

32422. (*Mr. Willis.*) Then, would that mean that if, at those places where we have had these complaints, they had settlement enough to allow the liquids to stand for twenty-four hours, would it remove the complaint?—I should think probably it would if they have the settling ground, but it requires, as I say, a large area to deal with it. Especially as on a china clay property, the landlord, as a rule, would not agree to any portion of this land, which may be bearing china clay, being covered down with anything like waste material. Even if your dam was an acre in extent, or say two or three acres in extent, if there is a bed of china clay under that, that becomes very valuable indeed.

32423. He wants that to be worked?—Yes.

32424. (*Chairman.*) Thank you! We are very much obliged to you Mr. Stocker, and Mr. Martin, for the very interesting evidence you have given us.

Mr. C. E. Munro Edwards, called in; and Examined.

Mr. C. E. Munro Edwards.

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32425. (*Chairman.*) You are representing the Dovey Conservancy Board?—I am.

32426. In what capacity, may I ask; are you a Member of the Board?—Well, I have been a member for a great number of years, but I am sorry to say I lost my *ex-officio* qualification last year. I am sent as a representative of the Board, having had considerable experience of the alleged pollution in question.

32427. Are you a riparian owner?—I was.

32428. On the Dovey?—No, I am on a tributary, on the Mawddach. The pollution is caused by a copper mining company, the Glasdir Copper Mining Company that discharges the liquid tailings into the Mawddach, a little over 2 miles above the tidal water. I might mention the spot to which the tide extends. That is Llanelltyd Bridge, and it is a little over 2 miles above that that the tailings from this Glasdir Copper Mine are discharged into the main river. Might I go on to tell you what I know?

32429. Yes, please?—The Glasdir Copper Mine has been worked intermittently for a considerable number of years. Shortly before 1898 the Company got a fresh lease from the owner of the estate, that is the late Mr. John Vaughan, and the workings recommenced in a very aggravated form. Very little was done to the old filtering beds, and the result was so disastrous, not only to the river itself, but to the property adjoining, as the silt after floods killed the herbage, that proceedings were taken in the High Court by private owners. I have a statement in regard to that. That was in 1898. An Order of the Court was obtained before the late Mr. Justice Kekewich. I think the form was a perpetual injunction.

32430. Yes? The Order, the injunction, was made by the judge, and it is now in force. That was on the 20th April, 1900?—I might mention that before those proceedings were taken, considerable pressure was put on the Company to make adequate catch-pits, but it appears that their profits were not great and they would not undertake to do so.

32431. Might I put some preliminary questions? I think we should like to be told by you, if you could tell us, how is the copper worked; is it actually smelted there or is it merely mined?—It is mined.

32432. No smelting?—No smelting; not in the Glasdir Mine.

32433. Because I know in Anglesey, the plan was to allow the copper ore to weather and then lead the liquor that came from the copper ore into tanks or ponds where it was precipitated. Nothing of that sort occurs?—I understand the process is the crushing of the quartz.

32434. They simply crush and wash ?—And the liquid is conveyed by wooden troughs into these, so-called, filtering beds.

32435. And then they take out the crushed copper ore and allow the refuse to go ?—Yes.

32436. And it is this refuse which you are speaking of which gets into the river ?—Yes.

32437. And which still contains a considerable quantity of copper ?—And we consider other poisonous liquid. I should be guarded in what I say, but I understand we have traced cyanide and sulphate of copper.

32438. Sulphate of copper ?—Sulphate of copper. Cyanide, I believe, is used, but the manager informed me that no cyanide escaped into the river. On the other hand, there are traces of oil.

32439. The cyanide would be used for gold, not for copper ; is it a gold mine, too ?—Well, they are working for copper and gold. Primarily, it is a copper mine, but they try to extract every metal, both base and gold.

32440. I think the manager is possibly right, because cyanide is a most expensive substance to use ?—I must be guarded in what I say. I have no proof that they use cyanide. I went into the Chemical Laboratory, but I did not go minutely into the question of the analysis with the man who conducted the chemical process to extract the copper. I have been over the mine ; of course, I have not any practical experience of it. I am only trying to explain to you, Sir, what is the result in the river.

32441. I wanted to be clear as to what gets into the river. It is the washings of the copper ore. The ore is crushed and then washed, and the copper no doubt kept behind and the washings, which no doubt contain some copper, get into the river ?—There is no doubt about that. Then the damage ; I suppose you would like to hear as regards the question of damage to the fishery ?

32442. We should like to hear that ?—The damage to the fishery is caused by this silt in suspension gradually settling at the bottom of the pools. If you were able to see the river as it is to-day, after a considerable period of drought, you would notice that it is a sort of sediment or deposit that covers all the rocks. It assumes a muddy form ; we call it slime sediment on the rocks and more slime on the gravel. That gets deposited on the bed of the river with very bad results to the spawning beds. I have a letter from the clerk this morning in which he desired me to point out the damage to the spawning beds. He desired me to state that the keepers reported that the principal area of the spawning beds was in the lower portion of the river which is affected by this substance flowing into the main river. Since Mr. Fryer, the Assistant Inspector of Fisheries came down—I think it was in 1909 —to inspect the premises, a correspondence took place between him and Mr. Gilman Brown, the Managing Director of the Glasdir Copper Mine. Mr. Fryer pointed out the system which they should adopt as regards these catch-pits. The catch-pits are situated on a bank and they overflow. It is impossible really to keep them clear of this liquid slime and sediment. Considerable banking is necessary even to do that, but, after floods come, the result is that the banks are broken down and the substance is washed into the river directly, and this has caused considerable damage. Mr. Fryer came down and a correspondence ensued, and he pressed the Company to adopt what he calls "The alternative system." That is a series of not less than three pits so arranged that, whilst one is receiving the tailings, another is standing motionless so as to thoroughly settle, whilst the third, having so settled and having had the supernatant water drawn off by suitable floating arms or other contrivances, is being cleaned out. Mr. Gilman Brown replied to the effect that he thought his plan the better of the two, and it was the one which he said was adopted in America, so he did not agree to Mr. Fryer's views. Well, they never did adopt Mr. Fryer's system. After these proceedings were taken the old Company expired and the mine ceased working. I do not think they found the industry financially a success, so they ceased working. Subsequently, I think it was in 1906, they commenced working again. The Company was reconstructed, and a new Company commenced working the mine again. Mr. Bevan, the present Manager, I must say, did take steps to try and clear the filtering beds out. Mr. Gilman Brown, of course, says that they could not afford to carry out the recommendations of Mr. Fryer. Their margin of profit, I think he explains, was very small.

32443. So it was not done ?—No, it was not done. I would like also to say that Mr. Gilman Brown, in his replies to Mr. Fryer, did not admit that the river ever had been polluted by the operations. His contention is, that it does not kill the fish. It is true it does not kill the mature salmon. They stand a good deal ; it is extraordinary what they can stand. Before these proceedings were taken in 1908, the late Mr. Partridge, who was very much interested in the matter, and was one of the subscribers, picked up fry dead, and Mr. Fryer says it must have a most disastrous effect on the spawning beds. Then, also I would like to add that great complaints are made by the tenants of the farms contiguous to the river at this point, before the Glasdir Mine.

32444. From the point of view of the cattle drinking the water ?—No, from the destruction of the herbage. It kills the grass. No weeds will live in it.

32445. Does the river overflow its banks much ?—It does ; it is liable. In that case the silt is washed over on to the adjoining lands and the grass is destroyed. It is very evident, and any person who looks up the valley from Llanelltyd Bridge would immediately see what is the cause of that. It looks as if it had been caused by fire, but it is the sand, the fine sand being washed over the herbage, and tenants have threatened to give up their farms, or in the alternative to get a reduction of rent. That is on the Nannau Estate, and the present agent of the Nannau Estate has been in communication with the manager of the mine about this matter. But you see it is a question of means. No riparian owner desires to go to law over the matter. And there is another view to take of it. It is undoubtedly true, nobody disputes the fact, that it gives a great deal of employment to the working men, the mining population in the district.

32446. Are there many ?—There are a good many, yes, a good number in Dolgelley and in the district of Dolgelley too, and in the neighbourhood it does give a considerable amount of employment, so there is no desire on the part of the riparian owners and the Fishery Board, that the industry should be stopped, if they would only take what they consider adequate steps to carry out Mr. Fryer's recommendations. I should like you to see the place yourselves and you would be very much struck.

32447. Yes, it would be an advantage ?—I do not know if I put my points clearly.

32448. I wish to ask you one or two questions about the length of the river. What is the length of the fishing part of the river ; the part of the river available for fishing ?—Oh, the watershed of the Mawddach, the main river, above the Glasdir Mine, about 4 miles to which salmon have access.

32449. Is there trout fishing, too ?—Trout fishing above the falls. That is not affected. That extends right up into the watershed of the Mawddach a considerable distance. There is another mine on the main river, the Mawddach ; that is the Gwynfynydd Gold Mine.

32450. Yes, I remember that ?—It has recommenced working, but they do not cause so much injury from my point of view as the Glasdir Mine.

32451. It is simply crushed quartz ?—It is simply crushed quartz. It causes the river to be muddy, and I should think undrinkable, but it is not full of sediment ; it is simply quartz. Then, there is the large watershed of the Eden. The Eden is a tributary of the Mawddach. It flows into the Mawddach about 1½ miles above where the Glasdir pollution is discharged into the main river. The two rivers join. The Eden joins the Mawddach at that spot at a place called Aber Eden, which is just about 1½ miles above where the pollution commences. The River Eden drains a very large area and the water is perfectedly pure. There is now an artillery camp not far off that. There is no pollution at all there.

32452. Are the fishing rights valuable ; do the riparian owners consider the fishing rights valuable ?—I am sorry to say I left the neighbourhood before I was certain I should give evidence. I should have liked to have given the rateable value of the fishing ; I could obtain it.

32453. It is very considerable ?—Yes, it is very considerable.

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32454. Is the river netted at its mouth ?—It is netted in the tidal waters. Colonel Scott of Penonaeu Ucha, a Member of the Fishery Board, has ceased netting because he did not wish to make a profit out of it, and he wished to encourage, if possible, the angling. It is a fact though, that the fish do run through if they can, if there is water sufficient, and when there is a considerable amount of water, it is not so aggravated. I am an angler and I have caught fish at a point, as I mentioned 1½ or 2 miles above where the effluent from the Glasdir Copper Mine enters the river, and the fish I caught there were impregnated with oil. On tasting them, everybody said they tasted of oil.

32455. That is owing to the lubricating oil of the machinery ?—That is the oil they use for extracting purposes. It is allowed to escape into the river and very often you can see it on the surface. It is very curious that the fish, even after they have been some little time in the fresh water above, do not lose that taste.

32456. Of oil ?—Of paraffin oil ; everybody has noticed that. Experimental netting, with the consent and authority of the Fishery Board, was carried out to see what condition the fish were in after the fishing closed, but beyond the colour and being lethargic, they were not anything like dead. There is a Report by the Chief Inspector of Fisheries—it is hardly material to this beyond that it is a Report drawn up by the Chief Inspector of Fisheries—in regard to the pollution by the Glasdir Mine in former years, and fish were picked up dead some distance below, and he considered the cause of their death was the choking from sand in the gills. Sand gets into the gills. Of course, it depends on the maturity of the of the fish. These larger fish will stand a good deal as regards their gill power, whereas the smaller fish would succumb very much quicker.

32457. Is there anything you would like to add ?—I do not think so. I wired to the Clerk to send me a sample, but I had to leave this morning.

32458. I do not think that is of very great importance. We should hardly be able to investigate it unless there is any specific case of fish having been killed. That you have not got ?—I have not got that. In regard to the fishing point of view, the damage is more caused to the spawning beds.

32459. We understand that.—It is very difficult to describe it to any person who has not seen it. It depends so much on the height of the water, but the river looks in a dreadful state when the water is low as it is now. It assumes a very bad form. And now for drinking purposes, whether the farmers allow their cattle to drink it or not, I cannot say. I should not assume they do ; they prevent them ; but I never heard of any damage caused to cattle or sheep by drinking it.

32460. We are very much obliged to you.

Mr. GEORGE BARGATE, Chairman, Devon United Mines (1906), Ltd., called in; and Examined.

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32461. (*Chairman.*) You have given us a copy of your notes of evidence, and you are Chairman of the Devon United Mines (1906), Ltd. ?—Yes.

32462. Before you go on, might I ask you what ores you mine ?—Tin.

32463. Tin entirely ?—No, tin with a certain proportion of arsenic in it.

32464. Do you recover the arsenic commercially ; is the arsenic recovery part of your business ?—Yes.

32465. Would you care to read this statement ?—It might save time possibly if you wish to, and then we could ask you questions about it ?—You mean the letter I wrote to you ?

32466. Yes, have you a copy of it ?—I have a copy of my letter.

32467. Perhaps if you begin at the second paragraph it would be better : "We have now been working these mines "—or shall we take it as read and put it on the notes ?—Yes. (*The following was the Statement handed in by the Witness.*)

"We have now been working these mines for about six years, and only once during that period have we had any complaint that any water passing into the river was injurious, and I hear that parties who are interested in the fishing are trying to work up a case and are going to cite this particular instance to our detriment. At the time the complaint was made to us, I investigated it. It appeared that some people had brought some cattle from Dartmoor, where they were in a starved condition, and put them on rich pasture which had a scouring effect, and they wanted to put it down to the water in the river, but by no possible means could they put it down in any respect to any water from the river, as I investigated it at the time and offered to have an investigation, and immediately this was proposed to them, I heard nothing more about it. I had no hesitation in doing this, knowing that there was nothing in any way hurtful being put into the river, to either fish, cattle, or anything else, and to instance it, the fishing, according to the reports for last year of the Fishing Association, was better in the River Tavy than it has been for many years. I have also had the question up and several interviews with Mr. Fryer of the Board of Agriculture and Fisheries, and he knows, as well as we do, that there is nothing from our property going into the river, that is of a hurtful nature. During the past five years, a chemist, whose name I do not know, but I think he is a Public Analyst from Exeter, has at various times taken samples of the water, and there has been nothing found of a hurtful nature. When we mine the ore it is crushed and passed through a very fine mesh on to concentrating tables to separate all the mineral from the debris, which is of a very fine earthy nature, and when the river is low discolours the water and prevents it flowing down quite clear. We have gone to great expense in settling pits, and can do no more than we are doing, and this the people are satisfied with, excepting a lot of old people who occasionally want the river to be clear at all times so that they can have a few hours in the week fishing, and if such a state of things had to be, we should have to stop our works entirely, throw out of employment about 100 people, and lose the capital we have expended of between £40,000 and £50,000. There are certain surroundings which I could very much better explain personally to the Commission. Replying to your enquiries :—(1) Upon what principles should the Commission proceed in framing recommendations ? I beg respectfully to suggest to the Commission that as the conditions in all cases vary, that they should have inspectors in different districts, if such a thing is necessary, who should have a chemical knowledge, and let them report to a Commission after an investigation of some months, in the same way that you deal with Inspectors under the Alkali Act. For instance, we have visits from Dr. Fryer of Bristol, and we arrange our work at his suggestion, and probably a similar arrangement in connection with what passes into the river, might be similarly dealt with and understood. (2) I can scarcely see how you could deal with Clause 2 without a great deal of expert information procured from an unbiassed source, and you could scarcely legislate for a matter that had not had one or two years' investigation. (3) The method which we adopt, and the only one which can be adopted, is to have settling ponds where the water flows into, and the debris settles before it goes into the river, and this we give careful attention to. (4) Manufacturers (if you term us such), like ourselves, do experience difficulty in sending clear water into the river, in fact, it is an impossibility to do so, but there is nothing of a hurtful nature to fish, cattle, or anything else, that goes into the river. (5) I cannot see that any alteration of the Law is necessary as far as we are concerned. The Board of Fisheries have the full powers, and I have always told Mr. Fryer of the Board of Agriculture and Fisheries, if he will meet me there and make any reasonable suggestions, they shall always be followed." Mr. Mathews, Secretary of the Board of Conservators, on various occasions has spoken about the matter, and tried to prove that we were putting something into the river that was detrimental to fish, and I have seen him, and said: "Now, what do you complain of ? There is nothing going into the river that is detrimental to fish in any way, but if you have any suggestions to make in connection with it—reasonable business suggestions, anything that we can do—come up to the works and see me, and we will see what we can arrange." I have done the same thing with Mr. Rundle, the representative of the Duke of Bedford, and stated that there is nothing going into the river that is hurtful.

32468. (*Mr. Willis.*) You say that nothing polluting goes from your works?—There is nothing that is detrimental.

32469. I see. What does go from your works?—There is a certain amount of very light debris that we cannot settle in settling pits. That will get into the river and slightly discolour the water, and that is what the fishing people grumble at.

32470. They say it injures the spawning beds and that sort of thing?—It does not injure the spawning beds; you have only to look at the fishing returns to see that.

32471. (*Chairman.*) Have your works been carried on for a long time; are they old works?—Yes, we have been working them for about six years.

32472. And before that date?—Yes, they were working, but I have not very much evidence as to what was done at that time. On the opposite side of the river they were worked for nearly 100 years. That is the Wheal Friendship Mine.

32473. Did they crush the ore in exactly the same way?—I think the same way, except that they refined arsenic, which we do not do.

32474. It is merely the crushings, the washed tin ore, the silica and slimes that are washed away from the tin, that get into your settling pits?—That get into the settling pits. We have first one settling pit, and then another, and we settle all the sand and the heavy debris, but there is a very little fine material, earthy material, that will float away and goes right down the river, and you could not settle it under any circumstances.

32475. Does it silt up the river at all?—No; not at all.

32476. How long do you let the water stand in the settling tanks?—We let it stand, as far as we possibly can; it is always going in and coming out, but it is over a large area—about two acres.

32477. So large as that?—Yes, we have taken every precaution, and every care.

32478. Do you use large quantities of water for washing the ore?—Yes.

32479. You must do that?—We must do that.

32480. Is there no means of returning the water after that you have washed?—No, it all goes by gravity, and we would have to pump it back.

32481. You do not pump back?—No, we do not pump back. If we had to pump back that would bring all the sands and slimes into the mill again, which we want to get rid of. I have been very anxious about the thing, because I hate anything that is likely to grieve anybody else, and I got Mr. Holloway, the chemist in London, to let his chief assistant go down with me, and I asked him if there was any means by which we could improve the conditions under which we were working, and he said: "No"; he said also that there is nothing going into the river that is detrimental to fish or cattle. The case that I thought might be brought up against us was that case of Oxenham's, which I referred to in my letter. This Mr. Matthews wrote to my firm about two or three years ago, and said he had a claim against us because some of Mr. Oxenham's cattle had died or had been injured from drinking the water in the river. I saw him, and said: "It is no use making a general statement to me." I asked him from what they had died; what was the cause of the death of the cattle; and said that if he would kindly investigate it, and let me have details, I would deal with it, knowing of course that at the time there was nothing harmful going into the river. I heard nothing further about it, and you know the farmers in our district are quite ready enough, if they think they have suffered any damage, to pounce down upon us; and the fact of their not having done so must prove to you that we are not doing any damage.

32482. Are you very far up the stream?—We are about 4 miles from Tavistock up the stream.

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32483. Is it alleged at all that the stuff you put into the river does not settle. but gets carried right the way down?—It is carried all the way down.

32484. It makes the stream dirty?—Slightly turbid. If there is much water in the river you do not notice it, but if any of our own people about the mine go out to fish, they fish in the water that comes into the river.

32845. I believe this is a sample straight from the river—Mr. Mathews left it with us—below the outfall of the United Mine. (*Exhibiting bottle of river water.*)?—That has come from Mr. Mathews?

32486. Yes.—I think, if you are to bring a sample like that, it is no use accepting one that is taken by a man who may be biassed.

32487. He told us it was practically what runs out of your settling tanks; it was the outfall water?—Some of it might approach that in discolouration, but only very small quantities.

32488. It was left here settling. I do not know whether it has been touched since, but apparently there is a deposit of about a quarter of an inch?—Something of that sort. It looks very much worse than it actually is, but if you will leave that standing anywhere for twenty-four hours, you will see that it has not settled. It is impossible for us to settle it more than we are doing.

32489 (*Colonel Harding*). We did notice this morning, Sir William, that it had not settled very much. There might be a deposit at the bottom, but there was a great deal of suspended matter, which evidently does not settle easily?—No, we have tried every means in our power to settle it. I was told also in Tavistock by one of the men who fish down there that it was the difficulty in connection with the Tamar, and not the Tavy. He said to me, "Your place is all right; you do not do any harm," but he said the difficulty was with the people who are having dredging operations up in the Tamar. The dredging operations I do not know very much about, but I do know that they have got about four pounds of tin, and they work it very much like using a steam navvy, and turn up a tremendous lot of stuff. Well, if they are putting that back into the river without any settling pits, they would do harm. For instance, if we ran the whole of our stuff right from the mill into the river, that would do harm, but I can show you big heaps where we settle it and take everything out except a little discolouration such as you have got there; and we would take that out if it were possible to do it. You asked me the question as to making laws to deal with this particular thing. Now, the conditions are so varied. For instance, ours is a totally different condition from what it would be for the people who are carrying on these dredging operations, and totally different from what you would have where clay works water is going in; and I think the best plan would be, before any legislation is considered in any way, that you should have inspectors for a year or two who would go round and consider the particular conditions of each particular work; because you might make laws which could be applied to us, that were necessary for some other industry but which would be hurtful to us, and probably stop the whole proposition, where we are actually doing no harm.

32490. I do not think it has ever been proposed that there should be rigid laws applied, without taking into consideration the particular kind of industry. It never has been a proposition?—I did not know, of course, how far your queries might tend in that direction.

32491. Is not Dr. Fryer, whom you mention here at Bristol, one of the Alkali Inspectors?—He is one of the Alkali Inspectors.

32492. Are you under that Act?—Yes, and he knows the works very well. Now, for instance, to show how careful we are in regard to that, we are building some new cooling chambers, and Dr. Fryer has said that we must endeavour to reduce the acidity that goes per cubic foot into the air from 11.50 to 1.50. Well, that is a very difficult thing indeed to do; but before putting up these new cooling chambers, I wrote to Dr. Fryer and said I would be passing into Devonshire through Bristol and that I would go there specially if he would kindly meet me. He did so, and we discussed it, because I want of course to do what is right in regard to it; and I got from him his ideas of what would be the best thing. and we are going to build our chambers accordingly; and if there was anything more

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in regard to that water going into the river that we could reasonably do, I have only to have it suggested to me.

32493. This leads to rather an important question. Supposing it were agreed to have inspectors on Rivers Boards, placed towards river pollution in exactly the same position as Dr. Fryer occupies as regards air pollution; would you consider that a satisfactory way of dealing with the question? You have experience of the Alkali Act, and experience of Dr. Fryer's inspection. A similar man dealing with the rivers would satisfy you, would it not?—I think so. I think that would be the best way. I have spoken frequently to Dr. Fryer of the Board of Agriculture and Fisheries. I have discussed it with him, and I said "Whenever you are down in that district let me know, and I will come down and meet you. I will show you what we are doing, and if you can make any suggestions I shall be only too pleased to follow them." I think some inspector like that would be very much better. At any rate, if I may suggest it, I would do that for a period and see the result, because I do not judge that the Commission are wishful to put such restrictions upon us that they might stop the industry.

32494. Oh, by no means. What we have recommended is this; that there should be constituted a number of River Boards in the South of England and elsewhere, which should be subject to a Central Authority in London, and in case of any dispute the Rivers Board would either settle matters itself, or report it to the Central Board, as to a superior Court. An inspector would be sent down to consider what the nuisance was, and how it could be got rid of?—So far as these Rivers Boards are concerned, so long as they are not local men.

32495. The idea of the Central Board was to avoid local influence?—If you have Government inspectors to report to a Central Board, perfectly unbiassed men with no interest one way or the other; but in a local place, for instance, the Fishery Board are apt to be biassed by what happens to suit them personally best.

32496. Yes, we are aware of that fact.

32497. (*Colonel Harding.*) I just want to ask you, in the washing of your ores, what is about the proportion of useful ore which you retain, the metallic portion?—About 2 per cent.

32498. Two per cent. out of the whole?—2 per cent. Let me see! With the arsenic, perhaps about 5 per cent. altogether.

32499. What becomes of the other 95 per cent?—The probabilities are that we keep somewhere about 12 per cent.

32500. Twelve per cent?—Twelve per cent., because I was thinking when I answered the question first as to what the ultimate result was. We will keep about 12 per cent. per ton of the ore raised.

32501. Would that be an average throughout the year so much as 10 per cent?—Yes, including tin and arsenic. If it were tin alone, it might not be more than 1½ to 2 per cent., but we get a great deal of arsenic in our ore.

32502. And you really retain metallic parts to the extent of 10 per cent.?—Yes, and then it goes away for calcination.

32503. What becomes of the other 90 per cent?—It goes into the settling ponds.

32504. How much of it is settled there?—Well, the whole of it is settled there, except the proportion you see in the bottle.

32505. That answer might possibly mean that 90 per cent. of what went into the settling pits remained there?—I should think of what goes into the settling ponds, there is not 5 per cent. of it goes away.

32506. Now, what is the extent of your settling ponds?—I should think our settling ponds are getting on to nearly 2 acres.

32507. And how are they constructed, simply an area surrounded by a bank?—Surrounded by a bank, and as one of these fills then we have got another prepared.

32508. How many separate ponds are there?—There were 4 when I was there last.

32509. Then, this material settles in the ponds somewhat rapidly, does it not?—Fairly rapidly.

32510. What is the quantity of ore that you crush per day or week?—We crush about 30 tons per day.

32511. And of that 30 tons per day, would 25 tons settle in one or other of these pits?—Yes.

32512. Would it?—Yes.

32513. Then, how often is it removed?—I think that is the proportion; I will get the figures for you.

32514. I merely suggest that to you; this is a mere guess on my part. How often is this removed from those ponds?—We do not remove it. As the pond fills up, when it gets up to a certain height, near the top of the bank, we run it into another, and then get another pond. It flows from one to the other, keeping settling all the time; and then when a pond gets full, we simply put men in and raise the banks, and get the banks up to a certain height so that we can use that pond again, and gradually, as the land fills up, we will have fresh land to take to do the same thing with.

32515. You do not remove the matter that has settled, but leave it *in situ*?—We leave it.

32516. And provide fresh settling ponds?—Yes, certainly.

32517. There may be a time when the ponds are nearly full, and when the water practically runs over the top of the settling ponds?—Never! We never permit it.

32518. Have you any data of the suspended matter in the final outfall?—No, but I can get that for you.

32519. Do you take any note of it?—No, we judge more by the appearance of it.

32520. And you suggest that the sample before us is not a fair sample of what goes from your works?—It looks to me from here as though it is not a fair sample; it is worse than it actually is.

32521. But we should not be wrong in assuming that a very large proportion of the suspended matter that passes into the settling ponds comes away into the river?—No, not a large proportion; a small proportion.

32522. What percentage would you suggest to us?—If you would permit me, I would like to get the actual figures from the works, so that I may be correct in the information I give you.

32523. If you put it in round figures that you retain 10 per cent. of the crushed ore as useful metallic material, how much of the remaining 90 per cent. do you suggest to us may possibly go into the river?—It would be very difficult for me to tell you.

32524. Well, would it be a half or one-tenth?—It would not be one-tenth.

32525. Not one-tenth part?—Not one-tenth part.

32526. Therefore, not 9 per cent. of the original proportion?—No, not one-tenth part would go into the river. We have been working and treating large quantities of ore in our time for six years. If there had been much of it going into the river, you would have found it along the banks of the river in serious quantities, and there is nothing of the sort.

32527. You said you dealt with how many tons a day?—We are dealing at the present time with about 30 tons a day.

32528. If you deduct the 10 per cent. which you usefully get back, that leaves 27 tons?—Yes.

32529. Do you think that one-tenth part of that only goes into the river, namely, 2·7 tons a day?—Well, it might. I would say about one-tenth of it goes into the river.

32530. You see that one-tenth is a material figure; nearly 3 tons a day?—No, there will not be that quantity. You see it goes in with a large volume of water.

32531. It is suggested to us that a much larger proportion than your 10 per cent. goes?—No, that is wrong, but I will get accurate figures for you.

32532. Well, these figures are somewhat material. I think for your own sakes, you ought to take samples and find what is the suspended matter; it is not a difficult thing to ascertain?—No. I will write to our chemist to-day and and I shall be down there on Friday, and I will tell him personally to make it so that you can have accurate information.

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32533. Is it not possible for you to carry your sedimentation further than you do ?—No.

32534. Why ?—Because we have gone to all the expense we possibly can. If we were to carry it in settling pits all the way down to Tavistock, you would still get some discolouration.

32535. You suggest to us that some of this matter settles so slowly ?—Settles so slowly that it will be carried out to sea.

32536. Have you experimented to assist the settlement in any way by the use of alumina or any other matters ?—No ; if we did anything of that sort we might start to do something that would be injurious to the fish.

32537. But you have not, in fact, experimented to assist the settlement ?—No, nothing but what would settle naturally. Is it your desire that I should get some further particulars in regard to this ?

32538. (*Chairman*). As regards the actual stuff that you turn out ; I think we should like to know, if you could give it us, particulars as regards the amount of suspended matter in the liquid and how much of it you turn out ?—Very well ; I will send you exact figures.

32539. (*Colonel Harding.*) It has been suggested that from some mines, if not from yours, nearly the whole of the stuff that is not retained usefully is turned into the river ?—Yes, that is the point I was making. That is probably causing the trouble at the present time. We mine underground, and that is why I am so positive that nothing can go from the concentrating tables, which is where the water goes from. I may cite to you that in a river, where many people think arsenic might be hurtful, it is exactly on the principle that where you have a river flowing through a limestone formation, your trout do exceedingly well there, at least it does not hurt the fish, but if you take that lime-stone formation and calcine it, and then put the calcined product into the river, it would be hurtful.

32540. But if you are working 30 tons a day, and you are merely usefully keeping 3 tons a day, there are 27 tons of waste. Now, are you really settling on your premises these 27 tons a day ; you say you never remove anything ?—We never remove anything.

32541. If you multiply 27 tons by the number of days in the year, that means a very big accumulation. If it is not on your premises, if goes into the river ?—There is a certain proportion of it goes into the river, and I do not think you can ever stop going into the river, without you stop the industry altogether.

32542. (*Chairman*). Would you mind sending us those particulars and they will go into your evidence. When you get your proof of evidence, you might add those ?—I will do so.

PARTICULARS REFERRED TO ABOVE.

1. The quantity of ore passed through the mill per year for the last five years, including what we are doing at present :—

Year 1906 = 1,827 tons
„ 1907 = 2,695 „
„ 1908 = 3,711 „
„ 1909 = 4,121·50 „
„ 1910 = 6,178 „
„ 1911 = 1,805 „ to 6th May.

2. The percentage per ton of the mineral product procured from each ton of ore passed through the mill :—

Black tin = 24·07 lbs.
Arsenic soot = 2·80 per cent.

3. The percentage that goes into slime pits :—

Black tin = 1·56 lbs. per ton.
Arsenic = ·90 per cent.

4. The amount of slimes that we have on the property :—

22,655 tons.

5. The percentage of matter that flows into the river :—

1·08 per cent. or 5 cwts. per day (24 hours).

It is important that the Commission in considering any legislation in connection with this matter should take powers to enable the owners of mines to acquire on reasonable terms the necessary land to enable the said owners to carry out the work that they may by such legislation require.

ONE HUNDRED AND SECOND DAY.

Thursday, 20th July, 1911.

PRESENT :

The Right Hon. The Earl of IDDESLEIGH (*in the Chair*).
Colonel T. W. HARDING, J.P., D.L.
Sir WILLIAM H. POWER, K.C.B., F.R.S.
Mr. R. A. TATTON, M.Inst.C.E.
Mr. F. J. WILLIS.
Mr. R. H. H. KEENLYSIDE (*Secretary*).

ALSO PRESENT :

Dr. GEORGE MCGOWAN.
Mr. C. C. FRYE.
Mr. G. B. KERSHAW.

Sir E. STAFFORD HOWARD, K.C.B., Chairman of the Wye Fishery Board, called in ; and Examined.

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32543. (*Chairman.*) Perhaps we may put on our Minutes of Evidence the statement you have been good enough to give us. It will go back to you, of course, for any corrections ; you will see a proof of it ?—Yes.

32544. It is useful to get it on just as it stands ?—Yes. (*The following Statement was handed in by the Witness.*)

NOTES ON THE POLLUTION OF THE WYE AT LYDBROOK AND REDBROOK IN GLOUCESTERSHIRE.

There are tin-plate works at both the above places which have been in existence for very many years, and employ a large proportion of the population of the respective villages where they are situated.

They use a very strong acid for dipping the plates into, and this acid when discharged either from the dipping tank or the washing tank discolours the water to a very serious extent ; but as it does not appear to be prejudicial to fish life, no fish being killed by it, the Board of Conservators are unable to take proceedings to prevent it. For a very long time past the Riparian Proprietors appear to have made no objection to the discolouration of the river by these works as it does not appear to have interfered

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with the netting of salmon to any great extent, which was then the chief method of fishing carried on.

Since, however, rod fishing has become so much more valuable, and netting in the river has been prohibited by bye-law, great complaints are made by the rod fishers that the "pickle water" is sent down so constantly that it seriously interferes with the value of the fishings. Arrangements have been made with the Redbrook Company to send down their "pickle water" at night which has to some extent met the complaint, but there are difficulties in the way of this at Lydbrook which have not as yet been overcome.

When pressed to take steps of an expensive nature to try and cure the evil the companies declare it would be cheaper to close these works and transfer their business to other places; this would, of course, be very hard upon the local population of the two villages who would lose their means of living to a large extent; but on the other hand it is a great pity to see a beautiful and practically unpolluted river like the Wye so spoiled by the acids poured in from these works.

If the Commission think it worth while, I could come and give evidence about these works or could depute some one else to do so.

32545. You are, I think, speaking solely from a fishery point of view?—Yes. To some extent from the point of view of the beauties of the scenery also.

32546. May I ask you, besides the efforts which have been made by the Fishery Board, what efforts at purification have been made by the County Council or any other authority?—I think you said the Fishery Board. The point is the Fishery Board cannot do anything in this case, because it is quite clear that this pollution does not kill the fish, and unless you can prove that fish are killed, so I am advised, the Fishery Board has no *locus standi* to interfere. What the County Councils can do I do not know, but as far as I am advised at present the only persons who can take action are the owners of the fisheries who find their fisheries are damaged by this effluent, and it is as representing the Crown, the owners of the fisheries, and some of the neighbouring owners, that I have been trying to bring pressure to bear upon these two Companies to reduce the nuisance as much as they can.

32547. But you are not aware of any complaints that the County Council have taken up?—No, they have not.

32548. And there have been no complaints as to spoiling the water of the river for human beings for drinking purposes?—I have heard of none.

32549. You have heard that there are complaints?—I have not heard of any.

32550. You are speaking practically from the fishery point of view?—Yes, the fishery and the beauty of the river.

32551. (*Sir William Power.*) In the third paragraph of your memorandum you say that rod fishing is damaged by the "pickle water" which is sent down. Do they habitually send down pickle water? Does it not pay them to get the iron sulphate out of it?—Well, the uppermost of these two works, the Lydbrook works, have a proper copperas plant, and they do keep the pickle water out. They make a certain amount of copperas, and the remainder is evaporated. I went over it myself not long ago, and I found there none of the pickle water does go into the river, but what causes discolouration is the wash water.

32552. That is the swilling water?—Yes.

32553. That is acid too?—That is acid too, and it mixes up with the rust, with the stream in which there is a certain amount of lime, which produces this discolouration.

32554. The swilling water is in large volume?—A large volume. There is a very considerable quantity going down always, because they are continually using the swilling tank. The first water is not much discoloured, but as they go on dipping and dipping their plates it gets thicker and thicker, until at last it is as thick as pea soup, and colours the water accordingly.

32555. You do not think the water, as acid water, is deleterious to the fishing in any way?—Well, it does not kill the fish.

32556. It does not kill them?—No, because it gets so diluted with the action of the river.

32557. Does it affect the food on which the fish feed? I should have thought it must on that side of the river where it is perpetually going down. Of course, it is worse in a dry summer like this when there is comparatively little water.

32558. It is more concentrated?—If we have a sudden flood, it does not matter so much. This year an enormous number of fish died. I would not say it is because of this particular pollution, but because the river has got so very low. In many places it has got stagnant and thick, and the water is very hot. Some time ago we had reports of large numbers of fish dying; coarse fish, salmon, trout, and all kinds, not only at this part but up above, and that shows there are other causes besides this, but I should think this would contribute to it to some extent.

32559. (*Mr. Tatton.*) You say it is the upper works that have adopted means of recovering their copperas?—Yes.

32560. The upper works only?—The upper works only. It is not a paying process I am told, and the people at the lower works declare it costs too much money, and if we force them to undertake any expensive methods of recovering this copperas they would have to consider the question of removing their works altogether, and that means that the village which lives by its labour in the works would lose its means of occupation. I think there are about 170 men and boys employed in the lower works and those are the ones which are not so up to date as the upper ones, the Lydbrook works. What they have done to meet the views of the fishing people is to store the water as much as possible during the day, and let it out at night when people do not fish, but that does not prevent the discolouration of the water.

32561. It kills the fish just as much?—So far as it kills the fish it does, but it does not interfere with the fishing so much because people do not fish in the night but during the day. It takes four or five hours for it to get clear away when the river is running ordinarily. In the dry season it takes much longer.

32562. I suppose the fish will not rise when it is coming down?—No, they lie stupid, and will not move.

32563. And if the upper works can treat their waste without serious detriment, would it be fair to ask all the works to do the same?—The fact that they are able to prevent the pickle going in water from the upper works, and the wash water appears to pollute the river just as badly as from the one below, shows that the wash water is the thing to deal with. It is no use dealing with the one without the other. I have some experts who have been over this Lydbrook works to see if they cannot recommend some course to deal with this wash water. The trouble at Lydbrook works is that there is a mill just below the works, and the miller will insist on having all the water to his mill; otherwise they might have taken the water into certain tanks and taken it away; and that makes an extra difficulty because there is this second interest down below.

32564. Is the wash water the swilling of the plates after they have been dipped in the acid?—Yes. They wash them over again after they have put them in a very strong pickle. They dip them in this tank, which has water running through it constantly for the purpose of washing off the remainder of the rust which may not have been taken off by the pickling tank.

32565. Could they not reduce the volume of the wash water considerably and use it over again for pickling?—That is what we should like them to do, to collect the wash water in tanks, and use some sort of precipitant to get this rust down to the bottom, and then let off the effluent by itself at a different time, and clean out the tanks. Of course, that would mean a certain amount of expense put upon them, but I think they ought to do it.

32566. You think it is a fair expense for them to be put to?—I think it is. Of course, they have been doing this for years without protest. That is the trouble. They are very long-established works, and have been doing this for years without protest. Since there has been a change in the fashion of fishing it has become a valuable property, and we say you must not do this any longer; but equally it is a thing they ought never to have been allowed to start, to pollute all these beautiful streams.

32567. Have you any estimate of the cost? Have you gone into that at all?—No. we have not gone far enough with regard to that. I am bound to say the managers of both the works said they would do anything in reason, but they would not do anything which they thought would seriously hamper them financially. That is a question of degree. We have not gone far enough to say whether we are justified in forcing them somewhat. Of course, if we could get an expression of opinion from a body like this that these things ought to be stopped, provided we do not put unreasonable conditions on those who are responsible for curing them, it would be a great help to us in trying to keep the river pure.

32568. (*Colonel Harding*). This process that you have been telling us about of the washing of the plates, is it continuous or is it intermittent ?—Oh, it is continuous.

32569. Then is there a continuous flow ?—Yes.

32570. You said it became worse after the washing had been proceeding for some time, and became like pea soup ?—Yes, it does. There is a certain amount of over-flowing most of the time; there is just a little dribble into the washing tank going on.

32571. It pollutes; the whole contents of the tank are discharged ?—Yes; when they have finished certain plates, they take out the bottom of the washing tanks, and the whole thing swills out into the river.

32572. Has it not occurred to you they should have a store tank, not to discharge during the night, but to discharge continuously during the 24 hours, when probably the volume of the discharge would be so relatively small as not to do much injury to the stream ?—You mean to take a big stream through the washing tank; let the whole stream run through as it were, dipping the plates in the stream as it goes by ?

32573. No; that is not what I mean. What I mean is, instead of discharging these vats or tanks when they get into the condition which you describe as pea soup, instead of discharging them into the river, they should discharge them into a store tank, and the flow from the store tank should be continuous during the whole 24 hours, so that the volume of flow per hour or minute would be relatively small. You would not have any of these rushes of polluting matter. That of course has been carried out in certain towns in the North of England with very great advantage. It has been found, for instance, that this particular pickle water coming wholesale at certain moments in the sewers did injury, whereas if it is stored up and let off very gradually and steadily during the 24 hours, where it is mixed with sewage, it does good rather than harm. It occurred to me that this was a somewhat obvious suggestion to make. I am surprised it has not been tried?—I quite see the point; that might improve it. Certainly it would do so when the river was fairly high. When the river is low, this small discharge seems to discolour it very much; it seems to grow after it gets into the river. It grows and extends, and finally discolours it for a couple of miles.

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32574. Have you dipping works which discharge strong acid into the river ?—The lower works used to.

32575. That you think is inexcusable ?—I think we have stopped them doing that.

32576. They can recover copperas in order to recover a large part of the cost ?—They can recover a large part of it, but they say it does not pay the expense.

32577. But it covers a large part of the cost ?—Yes.

32578. But dealing with these weaker washing water is a more expensive matter ?—Yes, it would be.

32579. (*Chairman.*) Thank you very much.

Mr. George William Ladds, called in; and Examined.

Mr. George Bargate, Devon United Mines (1906) Ltd., recalled; and further Examined.

32580. (*Colonel Harding*). Mr. Ladds, you come here as representing the Devon United Mines ?—(*Mr. Ladds.*) Yes.

32581. I think we have had some evidence already in connection with those mines ?—I supplied some figures which I believe you have.

32582. You did not yourself give evidence here ?—No not myself.

32583. Could you remind me who it was gave evidence the time before on behalf of the mine ?—(*Mr. Bargate*) I did.

32584. I remember you, now. What is the object in coming before us in regard to that mine again ? Is it for the purpose of putting before us additional facts ?—(*Mr. Ladds.*) More for confirming the figures Mr. Bargate gave, I believe.

32585. What is the total amount you deal with per day ?—From the course we have taken, we estimate that we put in about 5 cwts. a day of 24 working hours.

32586. But what is the total material you deal with; the total tonnage ?—22,000 tons, I think, Sir, if I remember right. I have given it from 1906 to 1911 for each year. I think you will find it at the end of these notes.

32587. I think the evidence put before us before was that you dealt with 30 tons a day ?—Yes.

32588. And you withdraw and keep as useful material some 10 per cent. of that ?—Not 10 per cent.; 1·08 per cent.

32589. We were told that you retained 2 per cent. of the whole ?—Yes.

32590. But there were other matters that you retained besides those included in the 2 per cent. Is that so ?—(*Mr. Bargate.*) Might I interrupt for one moment. I think it is my evidence that you are giving. I said I was not accurate in regard to the figures which I was then talking about, but Sir William Ramsay, who was in the Chair, asked me if I would give the accurate figures, and I think you will find that the accurate figures are at the end of the report.

32591. But you did say, whether rightly or wrongly that you kept somewhere about 12 per cent. ?—So far as I could state, but I could not state accurate figures.

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32592. And, finding you were not certain about 12 per cent., I suggested to you a round figure of 10 per cent., with which you seemed to agree ?—Yes, I said I was not at all certain and I would get the accurate figures; and I think if you will look at the last Clause there, you will see the Chairman asked me if I would send him accurate figures, as the figures I was giving were simply guess work.

32593. Then Mr. Ladds is here to give us more accurate information. Is that it ?—Yes.

32594. Now, you deal with 30 tons a day, and how much of this matter do you usefully keep back ?—(*Mr. Ladds.*) We keep back over 99 per cent. of it.

32595. Let me put it another way. What metallic parts do you keep back ?—Of metallic parts, we save 24 pounds of tin on the average per ton.

32596. Would you mind giving it me in percentages ?—Well, I have not worked it out. It is over 1 per cent.

32597. The evidence before us first was that you kept back 2 per cent. out of 30 tons ?—Well, it is hardly that; but it is over 1 per cent.

32598. What other useful matters do you take away from this raw material ?—We save 2·80 per cent. of arsenic.

32599. Can you give me the total percentage of what you do retain ? I am asking you this to ascertain what is the amount of the waste product out of 30 tons. Is it 27 tons, 90 per cent. ?—Roughly, it is about 27 tons waste every day saved in the settling pits. The remainder is the mineral that we recover; 2 per cent. or 3 per cent. altogether. (*Mr. Bargate.*) I should think nearly 4 per cent. (*Mr. Ladds.*) About 3 per cent., including arsenic, of metal saved.

32600. And the matter which is of no service to you is 27 tons a day ?—Yes.

32601. What I wanted to know before was how much of that went into the river ?—5 cwts. a day goes into the river.

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32602. Where does the remainder go ?—The remainder goes into the settling pits.

32603. How often is it removed from the settling pits ?—It is not removed ; the banks are gradually raised from the matter in the pits.

32604. With 27 tons a day, in the course of two or three years you would get a very considerable addition to the soil, would you not ?—We have about 22,000 tons now on this particular site ; 22,000 tons of this debris on this particular site at the present time.

32605. Then do you state to us that really the greater part of this 27 tons a day is actually retained upon your own storage land ?—Most decidedly.

32606. And that you are prepared to continue to retain it ?—Most decidedly.

32607. It does not wash into the river ?—Nothing goes into the river with the exception of this 5 cwt. a day.

32608. Per day ?—Per day. (*Mr. Bargate.*) A day of 24 hours.

32609. You are prepared to stand by that ?—(*Mr. Ladds.*) Certainly.

32610. You have sent to the Secretary of this Commission an analysis of the 29th June last. Do you wish it to go upon our Minutes—the analysis of Mr. Holloway ?—(*Mr. Bargate.*) Yes ; I suppose you are addressing me in regard to that. I think the letter was sent by me. Yes, I want it to go on the Minutes.

32611. Do you think it of sufficient importance to go on the Minutes ?—I think it is, so far as there being anything hurtful going into the stream is concerned, and it also shows that a long time before we learned that the Commission was likely to question us in regard to the matter we were taking due precautions. The letter is dated some time ago. We took these samples prior to any communications from the Commission, endeavouring to see that nothing of a hurtful nature was going into the river ; and on that account I would like it to go into the evidence. (*The following is a copy of the analysis referred to.*)

9 to 13, Emmett Street,
Limehouse,
London, E.
June 29th, 1911.

The Devon United Mines (1906), Ltd.,
7, Arundel Street, W.C.

Dear Sirs,—As instructed by Mr. Bargate, I have examined the sample of water which was collected and sealed by Mr. F. Rowley on September 12th, 1910. The bottle was sealed in wax, "F.R." and had been kept unopened until now.

The sample consisted of one Winchester quart (about $\frac{1}{2}$ gallon) of water, containing a small amount of finely-divided sludge resembling clay in appearance and taking a considerable time to settle after being shaken up.

It may be pointed out that the sample was an independent one taken by Mr. Rowley, but that it cannot be regarded as showing definitely the amount of suspended matter in the effluent from which it was taken. It is, however, a representative sample of the water overflowing into the river at the time, from the tailings dams.

The water was found to be free from smell and to be alkaline in reaction. It contained no lead, copper, zinc, arsenic or other impurity likely to be injurious to fish or cattle. A small amount of iron, lime and manganese was present as is usual in ordinary waters.

The total mineral matter amounted to 75 grains per gallon. It was of a grey-buff colour and showed the usual reactions for clayey matter. No tin, arsenic or copper was found it. It was an extremely finely divided condition, and Mr. Rowley informs me in a letter dated yesterday, that, when he collected it, there was practically no settlement in the first 24 hours.

Yours faithfully,
(*Signed*) George T. Holloway.

32612. Unless the Chairman has any further questions to ask, I will not press the matter further. In effect, what you have told us to-day is what you have told us before ?—Yes.

32613. (*Chairman.*) Thank you !

Mr. H. Clement, Welsh Plate and Sheet Manufacturers' Association, called in ; and Examined.

Mr. H. Clement.

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32614. (*Chairman.*) Perhaps you will be good enough to let us put this memorandum straight into the Minutes as it stands ?—Yes, my Lord.

32615. It is convenient to have it in that shape. You will, of course, have a copy of the Minutes sent to you for any correction you may desire to make in your evidence.—Thank you. (*The following Statement was handed in by the Witness.*)

Tin plate manufacturers already adopt every practicable means, and generally at considerable expense, to prevent pollution of rivers and brooks by the effluents from their works.

Practically all tin plate works manufacture sulphate of iron out of their spent or waste sulphuric acid when the works are situate on rivers and brooks, and even when otherwise situate, so that the only effluents discharged are the waste water overflow from cooling boshes, the water used for condensing purposes, and the swilling water in which the plates are dipped subsequent to pickling.

All these effluents are quite innocuous, and in the case of the swilling water or fluid mentioned in the letter of 16th May, this has been found by analysis to be absolutely harmless, and it is bound to be so inasmuch as a large volume of fresh water is continually running into the swilling tanks or vats in which the pickled plates are placed for cleaning, during operations and also during the periods when the plant is idle.

It may be mentioned that in cases of rivers or brooks into which sewage matter is allowed to flow, the presence of spent or waste acid containing as it does sulphate of iron would be more beneficial than otherwise.

32616. (*Mr. Tatton.*) A portion of your pollution is from swilling water ?—Swilling water, yes ; but we do not consider that can possibly be any pollution whatever, and I speak from knowing the analysis of the water that has been taken numbers of times. Perhaps I might explain the *modus operandi*, which will be helpful. In what we call the pickling department we have two tanks. In one of those tanks the plates are immersed in sulphuric acid. The spent acid from that tank is converted into sulphate of iron and does not go into the rivers or brooks. From here the plates go into a tank 6′ 0″ × 4′ 0″ × 4′ 0″ deep. There is a 4 or 5-inch pipe of water running continuously into that tank during the time the operation is proceeding and when it is idle. Say this is the tank here, putting it in this shape, the water is delivered here and the overflow goes away at the top, and we have had on many occasions that water analysed, and it is absolutely harmless, absolutely innocuous. It is quite impossible that any acid or any polluting matter could be in it.

32617. Have you got analyses ?—I have not got them with me now, but I know they have been taken. The actual acid used is about $2\frac{1}{4}$ tons per mill per week. Well, there are from 12,000 to 14,000 gallons of water used each day per mill, into which the plates are dipped, and it is utterly impossible—I speak from a practical knowledge of the trade extending over about thirty-six or thirty-seven years—for any pollution to occur from the swilling water.

32618. (*Sir William Power.*) Have you any fish in your river ?—Yes, we have had fish in the river, in the Towy, many years ago, but I believe there is more harm done to the fish there by the effluents flowing from collieries, the mineral water.

32619. But the fishermen do not complain now of this acid water ?—No.

32620. Because there are no fish or fishermen ?—I might tell you a rather peculiar thing in reference to that, to show the amount of injury that has been done. I do not think there has been any fish in the River Towy for the last thirty or forty years. That is where I live, and more than that, what we contend as tin plate manufacturers is this, that any impurity or any pullution that might occur would be in the shape of sulphate of iron, and that really and truly would be rather a benefit than the reverse.

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32621. (*Mr. Tatton.*) And I suppose you take your water from the river ?—Well, it comes from rivers and canals and usually it is run at a pretty good head, and you can imagine a 4 or 5-inch pipe flowing continuously into a tank of the size that I give, both night and day; and of course the operation is only going on by day, and I have not the slightest hesitation whatever in saying that there is no pollution.

32622. It is merely a matter of dilution ?—Yes, of course, that flows away. There is the overflow water from the boshes and the condensing water, and it is all mixed before it gets into the river or brook, because there is one channel leading from the works.

32623 (*Mr Willis.*) Do the County Council agree with you that the swilling water is innocuous ?—Well, the only enquiry we have had from the County Council was I think in January, 1909.

32624. Yes ?—And we as an Association have had no complaint whatever from them.

32625. They have never said it is noxious ?—No, never. We have several of our executive members on the County Council, and of course if any complaint was made there, any reference made to it, we would hear officially as it were from them, irrespective of hearing from the County Council.

32626. You have never been asked to treat your spent liquid ?—No, never. I have had a long experience of the trade, and I am certain there cannot be any deleterious matter.

32627. You say you have had analyses made ?—Yes. I have not had them made myself, not personally.

32628. But you mean your firm has had them made ?—Well, I am the Secretary of an Association which comprises fifty-three firms altogether—certain members of our trades and certain chemical manufacturers have made analyses.

32629. Do you know who has made the analyses for them ?—They usually make it themselves. In these chemical works, usually the managers are analytical chemists themselves.

32630. Are you a chemist ?—No, I am a tin plate manufacturer.

32631. (*Colonel Harding.*) You tell us that the swilling water from tin plate works is not only absolutely harmless, but is bound to be so ?—Yes.

32632. Because of the large dilution ?—Yes, the very large dilution.

32633. But are you not aware that serious complaints have been made of pollution from washing water ?—No, never.

32634. You have never heard of such a thing ?—Never; not from swilling water.

32635. By swilling water you mean exactly the same thing as the washing water from washing the plates after the dipping process ?—Yes.

32636. But would you be surprised to find that we have had evidence complaining of the polluting effect of these washing waters ?—Well, I would not be surprised, because I believe in one instance—the works at Llantrisant, not very far from Cardiff—there has been some trouble there, but officially, as an Association, we have not heard anything whatever of it, and it so happens that that firm is not in the Association. Moreover, any complaint that might arise on that score, I should say without any hesitation, that the swilling water cannot be polluting.

32637. I have before me an analysis of the water from the Ely Works ?—That is the works I refer to.

32628. Is not that a works you represent ?—No, they are not in the Association.

32639. And are their washing waters as harmless as your own ?—Of course, I do not actually know what their swilling water is, but I should say it would be similar.

32640. You would expect that they would be equally harmless ?—Equally harmless, yes.

32641. Well, the analysis I have before me shows that there were 312 parts per 100,000 of ferrous sulphate ?—Yes, sulphate of iron.

32642. And 325 parts of total acidity ?—What proportion would that be; 312 per 1,000 ?

32643. 312 parts per 100,000 of ferrous sulphate, and then there was this acidity, 325 parts, which is in the nature of waste ?—Yes.

32644. I suppose that is unavoidable ?—Unavoidable in a sense.

32645. They cannot wash away all the acidity ?—What we call the spent acid is made into sulphate of iron.

32646. Is this analysis from the Ely Tinplate Works an analysis representing the harmlessness of the liquor you are speaking of ?—Well, there are degrees. I would not be prepared to say whether that swilling water was innocuous or not, but what I should say would be that swilling water was perfectly innocuous. I know nothing of that particular water.

32647. What is the object of the swilling and washing ?—The object is to clear the plates of the whole of the acidity. The process is this: First of all, there is a tank and the plates are immersed in this. A certain quantity of steam is put in to make it boil. The acids themselves are hot. The plates are put in a cradle and worked up and down in a vertical position. This cradle, after what we call the pickling is done, is moved into a tank which contains nothing but water. There is a 4 or 5-inch pipe running into it at the bottom, and the overflow goes out at the top.

32648. All that I understand. What is it you put the plates through this process for ? Is it to wash something off ?—To take any acidity off that may have remained on them.

32649. Whatever the dilution there must be a certain amount of acid going in ?—Very very small.

32650. In the one analysis I have before me you see the acidity is considerable, and the amount of ferrous sulphate going forward is also considerable ?—I should not like to question anyone's analysis, but there is a very peculiar fact in connection with the works. I know as a matter of fact that some years ago the former proprietor was very much annoyed, I will not say humbugged, by certain people who had fishing rights there, and he closed the works; and it is a very singular thing that the next Company to take it had for its Chairman the Chairman of the Glamorgan County Council, because it meant that there was a matter of 300 or 400 hands thrown out of employment. I do not know what the date of that analysis is.

32651. The evidence put before us, rightly or wrongly, is that these acid waters do cause pollution ?—I very respectfully beg to differ.

32652. That is the other side of the question, and the one analysis I have before me, for which I believe the Commission's experts are responsible, says that the samples of the washing water they took were certainly very polluting ?—Well, of course, I cannot explain that.

32653. It makes us inclined to doubt your statement as to the complete harmlessness ?—I give my statement, and it is based not upon my experience only, but the experience of the whole of our Executive, because this evidence I have submitted to them. That analysis may be right, or it may be wrong, but if the analysis states that the quantity of acidity or sulphate of iron in it is injurious, then I very respectfully beg to differ. It cannot be.

32654. (*Mr. Willis.*) Suppose you had to treat this swilling water in order to make it purer than it is, would it be practicable to do it ?—If you imagine for a moment the Llantrisant works, it is a works of four mills, and I suppose there is something like from 12,000 to 14,000 gallons a day per mill used; that is the quantity of swilling water. Well, the quantity of acidity they would use would be only about $1\frac{1}{2}$ to $1\frac{3}{4}$ tons a day, and it is only the waste from the plates that can possibly get into this swilling water.

32655 You mean there is such a great dilution ?—Oh dear, yes. Assuming there is any acidity in the swilling water—which I do not admit—to evaporate that would take hundreds and hundreds of tons of coal.

32656. It would not be practicable ?—It would be absolutely impracticable.

32657. (*Colonel Harding.*) Do you strengthen your evidence by bringing forward any analyses of these waste waters, to show what the amount of the acidity is ?—No, *Mr. H. Clement.*

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I have not done that, because the matter to us as tin plate manufacturers is so very certain that I have not brought analyses.

32658. Our object is to investigate this, and we have statements on the other side, and we have to get the facts ?—You are speaking of the works of four mills, and we have in South Wales and Monmouth 521 mills. I represent directly 357 mills.

32659. Does this water run away continuously or intermittently ?—Oh yes, continuously.

32660. Continuously ?—The pickling process usually starts about six or half-past in the morning. There is an intermission of half an hour for breakfast, an hour for dinner, and they finish usually at four or five o'clock.

32661. There is no difficulty about getting samples at any time ?—Oh, no.

32662. You would put facilities in our way to get samples ?—Oh certainly, if you so desire.

32663. (*Mr. Willis.*) Is this swilling liquid acid to Litmus paper ?—No, the quantity of acid in the swilling water is so very minute that it could not turn it.

32664. Have you tried that ?—I have not tried that; the matter to us practical manufacturers is so very evident.

32665. You want to get back as much acidity as you can ?—There is no acidity there, because this liquid that the plates are put in first of all, is washed off, and does not go into the river at all. That is run into a float or into a tank, and it is made into sulphate of iron.

32666. But a certain amount of acidity adheres to the plates ?—A very very small amount.

32667. It is that which you want to wash off because it does adhere ?—Yes. Another factor is this in respect to the analysis that gentleman has given: I contend that, so far from doing harm to streams, it would do good. Sulphate of iron is in itself a deodoriser. We formerly used to send what we call copperas, sulphate of iron, up to London.

32668. To treat sewage with ?—To treat sewage with.

32669. Is there sewage in these streams ?—I will tell you a very singular fact. I can remember thirty or forty years ago, before the copperas plants were erected to treat this acidity and turn it into sulphate of iron, the whole of the sewage matter from where I live at Morriston was turned into the river. There was no complaint really, and there was no harm being done; but directly the works higher up in the valley commenced treating spent acid and turning it into sulphate of iron, the District Councils and the Swansea Corporation had to spend £50,000 on drainage schemes. I remember in Morriston, a place of from 14,000 to 18,000 inhabitants, we absolutely had no drainage. It all went into the river.

32670. But you are not saying the river is a suitable place in which to carry on sewage purification ?—Certainly not. I merely mention it to show the beneficial effect of even sulphate of iron. We are on the lime down there, and assuming that analysis is correct, the action of the lime in the brook ought to counteract it.

32671. (*Colonel Harding.*) What is the largest of the works that you represent ?—The largest is at Llanelly; 22 mills, employing about 1,100 or 1,200 hands.

32672. What would be the total volume of washing water from the largest works ?—From the largest works it would be a matter of anywhere from 250,000 to 300,000 gallons a day, and roughly speaking you can take it anywhere from 10,000 to 12,000, and in some cases 14,000, gallons per mill per day.

32673. Per mill ?—Per mill per day, and the way I arrive at that is that in some of the works they have to use reservoir water, and they charge the amount consumed, so that we know exactly the quantity.

32674. You suggest it would be a prohibitive business to settle or treat that small volume ?—Oh yes, it would be utterly impossible. Utterly impossible.

32675. Have you tried any settlement by lime ?—I believe at Llantrisant they have, and I should be very sorry to throw any doubt upon what they have done there, but that is a place I cannot understand. It is the only works that I know of that have been stopped owing to the difficulty with the County Council or the owners of the fishing. I have not known of any other in my experience of thirty-five or forty years.

32676. (*Mr. Willis.*) They actually stopped those works ?—The former proprietor was so greatly humbugged. He went to very large expense to run the whole of this waste swilling-water into a huge tank there as a sort of reservoir, and actually then they made out that some of it was percolating into the brook. I do not believe it for a moment.

32677. Because of the complaints he gave up his business ?—He gave up, and then the distress got so very acute there that the Chairman of the Glamorgan County Council, Mr. Jenkins, who lived near by, was the means of forming a new Company to restart the works.

32678. (*Chairman.*) Thank you.

Mr. John Whitworth, Mr. R. A. Thomas, Dolcoath Mine, Ltd., and Mr. J. Paull, Manager, South Crofty Mines, called in; and Examined.

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32679. (*Chairman.*) May I ask if Mr. Paull and Mr. Thomas will allow us to put in our evidence the précis they have sent us just as they stand ? It is convenient to have them in our evidence, the statements given as a whole ? (*Mr. Paull.*) Yes. (*Mr. Thomas.*) Yes. (*The following Statement was handed in by Mr. Paull.*)

South Crofty Mines, Ltd., are working what were some years ago, three distinct mines, viz., Old Crofty, South Crofty and New Cooks Kitchen. The quantity of ore raised from the various workings is approximately 62,000 tons per annum. In order to recover the mineral contents of the ore or rock as it comes from the mine it is necessary to crush the whole down to a fine sand, such crushing being accomplished by, firstly, rock-breakers, which reduce it to a maximum size of 2 inches diameter, and, secondly, by gravitation stamps which further reduce it to such a degree of fineness as to free the bulk of the mineral from the encasing rock. After leaving the stamps 40 per cent. of the ore will pass through a screen containing 40,000 holes to the square inch, the remaining 60 per cent. varying from this size to sand which would pass through a screen 500 holes to the square inch. Some 2,000 tons of tin, wolfram, arsenic and copper are recovered and sold, the remaining 60,000 tons being discharged into the Red River, except for a small amount of sulphur which is volatilized in roasting.

The Red River is practically a mine river, the bulk of the water, especially in summer, being that which is pumped from the mines on either side of its banks, and it has also been used by these mines for centuries for conveying the residues or waste from the ore down to the sea. The waste from the Crofty Mines consists chiefly of silica, with about 6 or 7 per cent. of iron in the form of oxides and sulphides, and it also carries small quantities of tin, wolfram, copper and arsenical pyrites which escapes from the concentration plant used on the mine. A portion of this latter mineral is recovered by various streamers along the course of the river, the waste after leaving the mines being reworked by them.

The mines at present using the Red River, with approximate tonnage of waste which each sends into it, and in the order of their discharge from the head of the river downwards, are, Grenville United Mines, approximately 40,000, Dolcoath, 100,000, South Crofty, 60,000, East Pool, 70,000, and Carn Brea and Tincroft, 7,000 to 8,000, or a total including one or two small producers not enumerated above, of about 300,000 tons per annum.

For the greater part of the year there is ample water to convey the waste down to the sea, but in the driest of the summer months the streamers have some difficulty owing to the river getting silted up, but I think this is caused by the streamers themselves by the methods they use in damming the river and constructing strips to divert portions of the stream from its regular course in order to collect quantities of the waste for treatment for its mineral values. If the river was not tampered with I think there would be sufficient water at all seasons to prevent the waste settling to any extent in the bed of the river.

As far as the character or contents of the waste discharge by any of the mines is concerned I do not think it can be of the least harmful nature to anyone along its banks, there being nothing in the waste from which any poisonous or other smells could arise. There may be traces of acid or mineral salts which would be harmful to vegetation if it came in contact with it, but as it does not come into contact with cultivated areas no harm is done.

If the use of this river was denied the mines it would be necessary to purchase land to store the waste products on, which would mean the destruction of the land so occupied, and in addition to this would create a nuisance in high winds through the finer particles being carried through the atmosphere. Ashes spread over such heaps protect the surface somewhat from wind storms, but even then a lot of fine sand gets blown over the neighbourhood, an instance of this being Carn Brea and Tincroft heaps.

Another method of dealing with the waste would be by returning it to the mine itself after dewatering, but this would considerably add to the working costs of the mines and there is in this method the possible danger of a sand run underground which might cause loss of life and cause great damage to the workings.

I have heard the point raised as to whether this same river might be used in connection with a sewage scheme for the town of Camborne, and, providing the bulk of the solids were taken out previous to discharging into the river, I see no objection to such a scheme. The point of outfall into the river would be below the streamwork industry, and as no part of the river is tidal there would be no trouble along its banks from smells, etc.

I do not know if the Commission wish me to give evidence regarding how to deal with waste from mines where such waste would cause pollution of hitherto clean streams or rivers. In such cases, except for the purchase of and destruction of land used for storage area it is quite a simple matter to make reservoirs of the waste itself, and allowing the water from such waste to go into the river quite free from solids, the addition of a small quantity of lime-water or alum will quickly settle even the finest slime particles, though china clay is perhaps an exception to this, and in the case of china clay it is more discolouration than pollution by solid matter. Very minute proportions of certain substances will discolour without harm. I have noticed Fishery Reports often favourable, as regards size and number of fish, even when the stream has been complained of in the same report as being polluted by certain mines and works, and in such cases I should suspect the so-called pollution was merely discolouration.

(*The following Statement was handed in by Mr. Thomas.*)

Dolcoath Mine has been in continual operation since 1799 and records are extant from 1776. It has produced during the past ten years 979,038 tons of tinstuff with an average produce of 41 pounds of black tin to the ton of stuff. The quantity of black tin sold is 17,946 tons, the monetary value being £1,526,780.

Dolcoath Mine, in common with other mines in the neighbourhood, crush by means of stamps their tin stuff, and after concentration, the tailings are allowed to go direct into what is known as the Red River, which conveys the sand to the sea at Gwithian, a distance of four miles. The tailings are worked by tin-streamers on the banks of the river, who in turn make all the extraction of tin their appliances will permit of. This custom of the mines discharging their tailings into this river has obtained ever since the mines have been in operation, and the river has doubtless been used for this purpose for some hundreds of years. As previously mentioned, Dolcoath discharges into the river about 100,000 tons per year; before, however, it reaches Dolcoath, Grenville United Mines discharge approximately 40,000 tons per annum, and others a few thousand tons in addition, and there are upwards of 300,000 tons of sand per annum carried by this river. At the present time, the flow of water is about 2,500 gallons per minute; this is much lower than is usual at this time of the year owing to the exceptionally dry weather. In the winter months the flow of water is twice as much as this, if not more; whilst later on in the summer, the flow would be somewhat less.

The solids in suspension from a sample recently taken is 2,942 parts per 100,000, and solids in solution 124 parts per 100,000. The water is faintly acid, and contains in solution, iron, lime, sulphates and silica. It is absolutely essential that the mines should continue to deposit their tailings into this river, as the purification of the effluent would be extremely costly, and in this particular instance would be a great blow to the tin-streamers who make a livelihood out of the waste from the mines, and employ a large number of people on their works.

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The flow of water is, in my opinion, quite sufficient to convey all the tailings, but the river occasionally silts owing to the streamers' operations, which frequently interfere with the free flow; this occasionally causes inconvenience, but I gather that arrangements have been made whereby a recurrence of this is not so likely.

At present the sewage from Camborne, after preliminary filtration, and the storm water, is conveyed into this river about two miles from the sea, which in the summer months is of considerable advantage in increasing the carrying capacity of the river, and also give the streamers more water for their washing operations; and I should add that their method of treatment is almost entirely by water concentration—on frames and tables of various designs.

I am strongly of the opinion that no alteration in the law is desirable as to the practise obtaining in regard to the effluent of the mines in this district.

32680. Copies, of course, will be sent to you, so that you can make any corrections you wish ?—Yes.

32681. There is one thing I wanted to ask particularly first. The Red River alluded to in your evidence is given up to mines wholly ?—(*Mr. Paull.*) That is the case; it is entirely a mining river.

32682. Is it used for no other purpose ?—No other purpose whatever except the mines, and the use of the streamers below the mines for reworking the mine leavings or waste.

32683. It has in point of fact been given up to the use of mines beyond the memory of man ?—I believe it has; I have never heard of it being otherwise.

32684. As regards Mr. Whitworth, the position is a little different, is it not ?—You come as the stream owner ?—(*Mr. Whitworth.*) Yes, as the stream owner.

32685. Have you any statement you would like to make to us ?—No, Sir; nothing more than that it is a natural mineral river; that is to say, it has been running through for centuries, taking the leavings from the mines and washing them out to the sea. No complaints have been lodged in any way.

32686. You have no complaint to make ?—None whatever, Sir. It is absolutely a mineral river. There is very little clear water going into it, and an absence of fish or anything in that way.

32687. Then I see you mention various heads of your evidence. Is there any particular statement that you would like to make ?—Well, Sir, I do not know whether you are going to introduce the question of sewage disposal in the river on the Camborne Drainage Scheme.

32688. No, we did not mean to enter upon that ?—Of course, all the mineral that goes into the river is produced on Mr. Bassett's property, the mineral lord. Three-quarters of the water is pumped from his mines by leases granted to the various mines at certain rates of payment; the water is his, the mineral is his, and the land through which it flows is his, so he is the most interested party, and of course he gets a large revenue from it. The storm water from the neighbourhood also flows into the river, and of course we are very glad to have it as tin streamers. At the mouth of the river, of course, it runs into the sea, and there is a natural silt back at times until rough weather comes, and then it clears itself very much. As I said just now, there are no fish in the river in any shape or form, and no oyster beds or anything of that sort, so there is absolutely nothing to complain of, except at this time of the year the slight absence of water; there is hardly enough to clear the mineral refuse. That is Mr. Bassett's own private property, and his duty is to provide water in case of shortage. I do not know that I have anything else to say to the Commission. If you are going to deal with the whole matter generally, I could say more.

32689. Apparently you are all pretty well satisfied with the present state of things ?—Yes, it is a most peculiar coincidence that this should be merely a mineral river, and nothing more or less.

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32690. (*Mr. Willis.*) Nobody complains to you at all ?—No one complains at all. We have no grievance, except with our landlord occasionally, and this is his private property.

32691. You mean he complains of the pollution of the stream running through his private property ?—No, because he gets a large income from it.

32692. I think you said you got complaints from the landlord ?—No, we have no complaints in regard to the river, but I am sorry to say we are rather handicapped in the way of the powers that be, by the high rates of dues we have to pay.

32693. You would like to get it cheaper, you mean ? We should all like to get our houses and lands cheaper, or for nothing.—Certainly.

32694. (*Colonel Harding.*) Mr. Paull, in the particular mine that you have come to speak to us about, you deal with 62,000 tons of ore per annum ?—(*Mr. Paull.*) That is so.

32695. And you get out of that 2,000 tons ?—Roughly 2,000 tons.

32696. You turn into this Red River 60,000 tons a year of waste matter ?—Practically so.

32697. What is the effect on the river ? Does it make it turbid ?—Well, the river is turbid before it reaches us.

32698. And does it make it worse ? It must do, of course.—Well, it naturally adds a little to the solids in the river, but the colour is not altered.

32699. In this particular case, the river being a short one, and no landowners in its short course being interested in interfering with your work, you gather that this may properly be allowed ?—Oh, yes.

32700. Because no objection is raised ?—Because no objection is raised.

32701. But what about the discharge of such waters into other streams which are in a different position, which flow for a much longer distance and have also valuable fisheries, and may possibly have residential and agricultural districts on their course ? What would be the effect of discharging large volumes like this ?—In that case I should say it would be an entirely different matter. I daresay, if it were carried on to a very large extent, it would naturally mean the destruction of the fish.

32702. Would you give us your opinion as to the methods that might be available for dealing with these waste waters carrying, as in your case, 60,000 tons of waste matter into a river ?—I think I mention in my evidence that, in that case, if the land might be purchased, we might purchase land to construct reservoirs out of the waste. That is what I had to do at the last mine I was on.

32703. These matters can easily be settled ?—Yes, they are easily settled. Of course, it costs a certain amount of money to settle it. In our case it cost about 6d. per ton of waste. We had to have a man or two men to look after these reservoirs, to see that the banks were kept properly constructed, and to keep raising the banks, and to see there was a sufficient amount of water kept in the reservoir, so that the overflow would go out perfectly clear. That and the cost of running the stuff into those reservoirs altogether would make up in our case 6d. or 7d. a ton.

32704. I am not suggesting for a moment that it is necessary in your case to do this.—Not now. That was on the Tamar.

32705. I am not suggesting it is, but if it were necessary to do it in the case of some other stream, is that expense an expense which you would consider practicable, or is it prohibitive ?—Well, of course, it depends entirely on the mineral value of the mine. If that is all the profit you are making out of the ore, you could not very well do it.

32706. As a matter of fact, many mines do settle these waters, do they not ?—Oh, yes, we had to do it on the Tamar on account of the Admiralty and on account of the Fishery Board, and that was the method we adopted.

32707. (*Mr. Willis.*) In your case you make an extra profit because of your exceptional position ?—Naturally it is worth more per ton, because we have not that expense.

32708. (*Colonel Harding.*) Do you know anything of the Devon United Mines ?—Yes, I know them.

32709. Are you aware whether they carry out any settlement ?—They do. They follow somewhat similar lines to those we had to at the mine I am speaking of—the Clitters United Mine on the banks of the Tamar.

31710. Have you any knowledge of the kind of effluent they turn out after settlement ?—Not at present. I have not seen it for three years. They had slime reservoirs or pits then.

32711. That may be looked upon as a case where it is found financially practicable to carry out such settlement ?—It is practicable provided you can secure the land at anything like a reasonable rate, but I believe the prices over there are very high indeed for land ; in fact, I think they are exorbitant.

32712. I wish to ask Mr. Thomas a question or two upon the same lines. I believe you represent a very important mine—the Dolcoath Mine ?—(*Mr. Thomas.*) Yes.

32713. What is the amount of ore treated in your case ?—Roughly about 100,000 tons a year.

32714. What do you retain in metallic products out of the ore, quite roughly ?—Roughly speaking, about 1,700 tons a year.

32715. Put it at 2,000 tons ?—Yes.

32716. 2 per cent ?—Something about that, yes.

32717. What becomes of the 98 per cent ?—It goes into the same Red River.

32718. The Red River ?—Yes.

32719. You are in the same fortunate position ?—We put our effluent into the river before Crofty, which Mr. Paull is speaking of.

32720. And I gather that the landowners on that short stream make no objection because they derive certain advantages from the fact of your carrying on this business ?—Oh yes, it is extremely remunerative to the landlords.

32721. But in other cases, do you consider it is financially practicable where nuisance is created in the stream and where objection is made, to effectually settle these large masses of ore ?—It can be done, but it increases the cost of operating to the extent Mr. Paull suggested—6d. per ton.

32722. I was suggesting to Mr. Paull that the Devon United Mines are said to carry out such settlement, and they themselves say that they do it very efficiently ?—Yes.

32723. I have no experience or knowledge of it, but if that is so, it would appear to me a thing which is practicable for a mine to carry out if necessary, is it not ?—Oh, yes, it can be done.

32724. It is not ruinous ; it would not kill the mine ?—No, probably not. At the present prices there is a fairly reasonable margin of profit, but when prices go down the margin is much less, and 6d. a ton might be prohibitive.

32725. Have you any experience of the kind of effluent that proceeds from such treatment ?—Other than a casual acquaintance with it, no practical experience.

32726. Is it fairly clear ?—Oh yes, I think so.

32727. It does not contain much suspended matter ?—Very little, I should think. I mean, very little in comparison with the comparatively large bulk of water in the river. It bears a small proportion to the river, and the other effluents would be——

32728. Would you think it possible to keep back by this process of settlement 90 per cent, of the matter which otherwise would go into the river ?—Oh yes.

32729. Quite possible ?—Oh yes.

32730. Then in your opinion, I may take it, that it is practicable to carry out such settlement if it be required ?—Oh, yes, it can be done, only it must be understood of course that the cost of doing it runs to about 6d. a ton, and occasionally when the prices of the minerals are low it is rather a serious encumbrance on the mines. Fortunately, in our district we are free from those necessities.

32731. (*Mr. Willis.*) Supposing the river were actually being damaged, would you consider it fair to require a mine owner to adopt purification ?—That is looking upon a river in a different light from what you would the Red River.

32732. Supposing you were going now to establish new works on a river where no works had previously been established. Assume that it is a good fishery river, but you were going to establish a large works there, and you did establish them, and you gradually injured that river. Would you consider that the Public Authority had a right to come to you and say: "Now, you must stop this injury?" Do you consider that is a proper obligation to put on the manufacturer?—I should imagine that the Public Authority would be justified in making some suggestion for the purification of the river, and I think in the majority of cases, that it would not be any great hardship upon the manufacturer or the miner as the case may be.

32733. No, but supposing a case where the cost of effective purification would be so high that the mine owner could not work at a profit, who would you say ought to suffer then? Ought the mine owner to be made to go under, or ought the persons who own the river, who had previously enjoyed a good fishing river and a beautiful river, ought they to suffer? What would be your view upon that point?—They might make martyrs of themselves in respect of the employment which the mines would give to a large number of people.

32734. But looking at it from the point of view of possible legislation, what would you recommend? Would you not say it is a sounder plan to say that the manufacturer must work under the obligation not to damage the river if he is to use the river for his purposes?—I should imagine that would be a view that would be likely to meet with approval.

32735. Do you think any other view is a sound one to proceed on?—Well, I must confess I am afraid it is not, although it is rather unfortunate.

32736. There is a good deal of give and take in this world, and people do not press things to extremes, but, as a matter of principle, would you say that?—I think those cases have to be judged on their own merits more or less. It is difficult to generalise, is it not?

32737. That raises another question as to whether you would be in favour of a universal standard for all effluents going into rivers. I gather you would not be. For instance, in your case you would say the necessities of the case do not demand any purification?—That is so.

32738. Therefore, no standard is necessary?—That is so.

32739. In another case, if you are establishing works on a good fishing river, would you say that some standard was necessary?—Yes. The difficulty would be, of course, to fix the standard, having regard to the danger of generalising.

32740. Then your rival who happened to be on a good river would say: "I am very much handicapped as compared with Mr. Thomas, because he has a river where he does nothing whatever, and he saves 6d. a ton which I have to spend." You would say he must put up with that if he selects that river to work upon?—That is an unfortunate handicap.

32741. And you would leave him with the handicap; you would not relieve him of it?—I do not see how you could relieve him of it.

32742. Your view is perhaps—many manufacturers have come here and said that all manufacturers should be put under the same obligation, otherwise you do not get fair trading; they press that view?—It strikes me as rather a peculiar attitude to adopt.

32743. You really would be in favour of variable standards according to the circumstances of each case?—In my judgment, I do not see how you are likely to solve the question unless you do so.

32744. (*Mr. Tatton.*) What would it cost? I think you mentioned a figure that it would cost you to recover the solid matter going down?—I quoted Mr. Paull, who has had experience of this matter, which I have not. Mr. Paull said 6d. a ton. In my judgment Mr. Paull is correct.

32745. Is the 6d. a ton on the gross output?—The gross output. At South Crofty, where Mr. Paull mentioned they were discharging into the river 30,000 tons, it would cost them £1,500 a year, would it not?

32746. Yes, and you produce 100,000 tons?—Yes.

32747. It would cost you £2,500 a year?—£2,500 a year, and I might add that we are at present designing to largely increase that output. We shall have considerably above 100,000 tons per annum.

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32748. What works would you have to put up to recover this? Supposing you had to treat it, what would you do? We should have to put down tanks to settle it.

32749. You mean earth-work tanks; you would not empty your tanks out I presume?—Stone-work tanks, I take it. In our district stone is pretty cheap, you know. They would have to be settled, roughly settled, first, and in the second instance, I think the introduction of a little lime facilitates precipitation. It all depends, of course, upon the purity demanded for the effluent.

32750. But does not the stuff settle very readily?—Yes.

32751. Because it settles in the stream all the way down, does it not?—Well, I do not know that it settles very much on the way down; it is worked all the way down. I had a sample taken a few days ago which might be taken as a fairly typical sample, with the exception, however, that at this time of the year the water is very little comparatively, owing to the dry weather, but that simply gave 2,942 parts per 100,000 solids and 124 parts per 100,000 in solution.

32752. Was that as it went away?—That was as it went away. That sample was taken below South Crofty, that is to say from a point where Dolcoath discharges 100,000 tons per annum, South Crofty 60,000 tons per annum, another mine above us 40,000 tons per annum, and a few odd thousands throw in, so that is roughly speaking a little over 200,000 tons per annum that passes through that river. I think that might be taken as a fair sample, probably on the high side as far as solids are concerned, due to the fact that at the present time the flow of water is rather small owing to the exceptionally dry weather.

32753. Do cattle drink the water; I suppose that is impossible? Oh, no.

32754. What about the cattle below the mines, are there any cattle at all?—You must have in your mind that for four miles there is practically an unbroken line of works by the tin streamers who have been working there from time immemorial catching the minerals which escape from the mines present operations, and there are no cattle to drink this.

32755. I see; they cannot get near the stream at all?—No, there are little streams running near by where they drink.

32756. There are some clean streams?—There are some clean streams. The water from the clean streams is brought in where they can get it for the purposes of the tin steamers who want to get as much clean water as they possibly can for their washing operations.

32757. (*Colonel Harding.*) Might I just ask you, Mr. Whitworth; you are engaged in a business in connection with this river and this waste ore?—(*Mr. Whitworth*) Yes.

32758. You extract metals from the waste which is discharged into the river?—That is right, Sir.

32759. And, therefore, any settlement by the mine owners would ruin your business?—Would destroy our industry absolutely.

32760. Is that industry an important one?—Oh yes.

32761. Are there many persons carrying it on?—Oh yes; I suppose there are about 600 people engaged in it.

32762. And their interest is simply in withdrawing from this considerable tonnage a small quantity of tin and other metals?—That is right, Sir. (*Mr. Paull.*) Might I qualify the statement I made with regard to 6d. a ton? I do not want you to think that that would apply in our case, or in the case of the Devon United where they have to pay high prices for land. At the Mine I mentioned just now, where I was before, where we did that, we had not to purchase the land at all, it was what was called Duchy Demesne land, land belonging to the Duke of Cornwall and we had no surface damage to pay at all. We could take in any land for mining purposes which we needed, consequently we had no value to pay for the land at all. If you had to buy that, of course it depends entirely on the amount of money you have to pay for the land. You have to spread that over the total as well; it would increase your cost.

32763. (*Mr. Tatton.*) Your cost was simply for works?—For works for settling, because we had to keep the Tamar quite clear.

32764. (*Chairman.*) Thank you.

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The Rev. Canon Sutton, Chairman of the Derwent Fishery Board, called in; and Examined.

32765. (*Chairman.*) I am afraid we have not had the statement that you have been kind enough to prepare ?—I am very grieved to say, my Lord, I understand from the Secretary it has not come. May I hand this to you ? This is the statement I sent to the Clerk of the Derwent Fishery Board, requesting him to send it on here. He sent me back my copy and I understood he had sent the other on here. (*The Secretary read the following Statement.*)

Pollutions in Derwent District—Cumberland.

Threlkeld Mining Company.—Four miles above Keswick where pollution is continually taking place. The lead mine is situated three-quarters of a mile from the Glendarmackin, a tributary of the Greta The effluent from the settling tanks runs direct into the stream, and from this point to one mile below Keswick dead fish have been taken out this year in large numbers. A sample of water and dead fish were sent to the County Analyst, Dr. Hellon, this year, and in his Report he says that probably the free sulphuric acid and zinc salt found in the water would account for the death of the fish, but he cannot say positively what caused them to die, but it is quite certain *something* is killing the fish in this stream which at one time was full of trout. The company being in liquidation, we can do nothing in the matter.

Thornthwaite Mining Company.—Another lead mine at the top end of Bassenthwaite Lake.

Here, again, the effluent from the tanks enters the lake. After heavy rains and gale of wind the sediment is disturbed in the lake which takes a week and sometimes longer to clear ; it is bluish-grey in colour, and the stones in the bed of the River Derwent for three miles down are covered with a deposit. On analysis, the water does not seem to contain any lead salts or poison of any kind, but it seems most probable that it affects the spawn, judging by the decrease in the number of young fish in this part of the river.

Dean Moor Colliery Company.—Water is pumped from this mine which flows into the River Marron, a tributary of the Derwent, and has caused the death of many fish. The Analyst's Report says : "This sample contains a voluminous brown sediment which is shown by analysis to consist very largely of hydrated peroxide of iron together with a certain proportion of protoxide of iron in solution. Protoxide of iron possesses an extremely strong affinity for oxygen, and on combining with it forms the red coloured peroxide which is so abundant in the sample—when therefore, the effluent containing this protoxide enters the river, the river water in the vicinity is deprived of the dissolved oxygen (air) which is naturally present in river water, and is essential for the breathing, and therefore life of the fish ; if, then, the fish are not quickly removed from this area of airless water, they die of suffocation. Moreover, the hydrated peroxide of iron readily clots into a slime, which if it adheres to the gills greatly interferes with their action and is fatal—ten fish put into a sample of this water were all dead in a few minutes." *No* settling tanks of any description are in use at this mine, and the water pumped from the workings runs direct into one of our best spawning grounds in the district. The company have been approached with a view of erecting settling tanks, but refuse to do anything in the matter.

32766. (*Witness.*) I should like to add that the Cockermouth Sewerage Farm and the Keswick Sewerage Farm happen to be so near the River Derwent that any flood sweeps the whole thing into the river. We have Cockermouth Sewerage Farm within about 100 yards of the River Derwent, and in the strong flood in the winter or spring the whole sewerage from the farm goes clean into the river. That is the same with the Keswick Sewerage Farm as well. The coal mines are a source of nuisance to us, three of them on the Derwent, the Buck Hill Colliery Company, the Camerton Colliery Company, and the Clifton one. Their catch-pits are so close to the river that after a flood the flood comes over them and the coal dust is washed from the pits, washed all into the river, and they damage our spawning beds enormously. They damage our spawning beds in the same way as the Thornthwaite Mining Company does. We do not think that the effluent from the mine does any harm to the fish, but when it gets into the lake, after a gale of wind or a storm, it is stirred up and it goes down the river. It has to go six or seven miles before it gets to the sea, and it spoils all the spawning beds on the river. As regards the Dean Moor Colliery Company, on the advice of the County Analyst, we are going to prosecute that company for not doing all they possibly could do as regards the Act of 1861.

32767. Are you going to take action against them ? Yes.

32768. Are you acting as the Fishery Board ?—Yes, as the Fishery Board.

32769. Now, may I ask, whether any authority besides the Fishery Board has interested themselves in these questions ?—No, not at all.

32770. Has the County Council done anything ?—No, the County Council leave it entirely to the Fishery Board. We applied to the County Council some years ago about the Threlkeld Mining Company to ask if they would take it up, but, after due consideration, they handed it back to us and we prosecuted them previously. We prosecuted the Threlkeld Mining Company in 1885 and 1889, but the Bench dismissed the summons on both occasions, thinking that the Mining Company had done all that they could possibly be asked to do as regards the Act of 1861. There is no fish in the river Greta now at all. The Company has been in liquidation for eight or nine months and there is no one to fire at.

32771. (*Mr. Tatton.*) Are you taking action under the Rivers Pollution Act, or what powers have you ?—Under the Salmon Fisheries Act of 1861.

32772. Then, does that give you power over mining water that is discharged from the mines ?—So I understand, if they have not taken every possible means to prevent the slaughter of the fish ; and the slaughter of the fish in the river just below where the effluent of the mine comes out is very great indeed. We have been given to understand that we have got a good case there, after receiving the County Analyst's Report which is copied here.

32773. (*Colonel Harding.*) What do you suggest to us that these people might do to prevent this pollution ? Put catch-pits down and get this water exposed to the air for some twenty-four or forty-eight hours, I think he says here, in order that the water may be purified in some way before it goes into the river.

32774. Then would there be considerable settlement in this case ?—Oh, no doubt there would be ; yes.

32775. But the water which would be in the tank would be deprived of its oxgyen, would it not ?—It is deprived of the oxygen now, because it is pumped up straight out of the mine into the river.

32776. The process which takes place in the river would take place in the settling tank ?—Well, but it would be exposed there for some hours before it was allowed to go from the settling tank into the river.

32777. And you think it would recover itself in the process ?—Yes, that is the view of the County Analyst ; we have only got his view to go upon.

32778. Have you reason to think that the expense of carrying out that process would not be prohibitive to the industry ?—Not at all. The Colliery Company is only a small one and they have got plenty of land. They jib at the expense, no doubt, very much ; that is their plea now.

32779. (*Mr. Willis.*) What would you do, supposing it were quite clear that the expense of removing your ground of complaint was so great as to really take away all the profit ; would you still go on and say they must remove the ground of your complaint ?—No, I think not. I am not sure whether I should do so or not.

32780. You feel that it is very doubtful whether they ought to be pressed to the extreme ?—No ; I would see if, in some way, they could be helped to do it.

32781 As a Fishery Board I believe you can only take action if you can prove that fish have been actually killed, can you not ?—Yes.

32782. Your powers are not anything like so wide as those of the County Council ?—Oh nothing like.

32783. Many Fisheries Boards have said they find very great difficulty in preventing pollution, because they cannot

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actually prove that the particular fish was killed by a particular pollution ?—Yes. I am sorry to say, although I have been a member of our County Council for a great number of years, County Councils are not very keen to move in the matter; they would rather throw the onus on the Fishery Board.

32784. Why should they do that ?—I do not know at all. That is what I find they have very often done. You have had evidence from the River Eden here, and they have thrown the onus on the Fishery Board, on the Eden Board.

32785. The Fishery Board's powers are so very limited ?—Yes.

32786. (*Sir William Power.*) Have not the County Councils powers for dealing with rivers that are polluted with sewage ?—No, they have not.

32787. They have power surely ?—They have power, but they do not care to exercise that power. I mean to say if there is no water being consumed for domestic purposes the power is rarely used.

32788. For instance, Cockermouth; did they adopt the Sewage Farm without any pressure from the County Council ?—That Sewage Farm at Cockermouth has been going on before our County Council.

32789. It is surface irrigation ?—Yes.

32790. Before the County Council was established ?—Oh yes, for a great number of years.

32791. (*Chairman*). Is the Derwent used for drinking purposes ?—No, not at all, or very little. It is pumped up at Cockermouth to supply the town of Maryport and Dearham, and the Maryport people have been keen enough to get it analysed and the report has always been fairly good.

32792. (*Colonel Harding.*) Might I ask, when is the case that you mentioned to us, likely to come on ?—The week after next. (Since giving this evidence, the Dean Moor Colliery Co. have ceased to pump out injurious water, so the Fishery Board have decided to take no action at present.—A.S.)

32793. Would it be possible for you to send us the result ?—Oh, I should be very glad to.

32794. (*Mr. Willis.*) Do the Cockermouth people use drinking water from the Derwent ?—No, that comes from Crammock or Loweswater lakes.

32795. They have recently carried out an enlarged scheme ?—Yes, they have. That is an excellent scheme. We supply Workington and Cockermouth and the neighbouring villages on the north and south side of the Derwent below Cockermouth.

Mr. JAMES ONIONS, Superintendent of the Dee Fishery Board, called in; and Examined.

Mr. James Onions.

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32796. (*Chairman*). You have come on behalf of the Dee Fishery Board ?—Yes, my Lord.

32797. Perhaps you will let us put this statement that you have drawn up straight into our Minutes ?—Yes.

32798. So that your statement will appear in our evidence. You will have a copy of it to correct if you wish to ?—Yes, my Lord.

I beg to state that I have been employed by the Board of Conservators of the River Dee Fishery District, as a Water Bailiff and Superintendent for the past eighteen years, and during that time I have acquired a practical knowledge of all the different sources of pollution and discharges that are turned into the river Dee.

The Dee is a very valuable and excellent salmon river being one of the largest in England and Wales, and from Bala lake to Chester weir is about 76 miles and having a gathering ground of about 686 square miles. There are several large towns, townships and villages in its watershed and also many works, mines and quarries.

The Dee Salmon Fishery Board spend a large sum of money annually in spawning and hatching out a very large number of salmon ova, and they are also carrying out interesting experiments in crossing the ova of the Dee salmon with the milt of Scotch fish, which, so far, has proved successful. This is done to try to keep up the stock and improve the quality of the salmon of the Dee from a commercial point of view.

There are several stone and slate quarries in the watershed of the Dee, notably at: Arenig, Glyndyfrdwy, Cefn and Glyn Ceiriog, but none of these have practically any regular discharge but occasionally an accident has happened whereby discharge of a noxious nature has got into the river and caused great damage.

There are several clay pits abutting on the Dee but none of these have as yet caused any trouble.

There are a number of collieries abutting on the Dee, all of which more or less discharge mine water and slack washings into the Dee. Several of these treat their discharge before putting it into the river by means of settling tanks.

There are a large number of factories, works and mills that discharge their effluent into the Dee without treatment some of which are very detrimental to fish and fish life.

32799. In the last paragraph of your statement you say that there are a large number of factories, works and mills that discharge their effluent into the Dee without treatment, some of which are very detrimental to fish and fish life ?—Yes, my Lord.

32800. Have you taken any steps against those factories ?—Yes, the Board continually has them under observation. Some of them are satisfactory, some of them are not.

32801. Has your Fishery Board taken any legal action against any of them ?—No, my Lord.

32802. And no other authority has taken any legal action, not the County Council or any other authority ?—No, my Lord. The Fishery Board are really the Authority that have the power, and they are doing whatever they possibly can to minimise the thing.

32803. (*Mr. Tatton.*) You say that several of these collieries treat their discharges ?—Yes, Sir, and their slack washings.

32804. Is that the water that they pump up from the collieries ?—They utilise that for the purpose of slack washing, washing the slack that is fetched up out of the mine to increase its value.

32805. They treat the water from the slack washing ?—The slack is washed and the washing from the slack washings goes down into the river.

32806. Do they not pass those through tanks, the water from the slack washing ?—Some of them do. The Wynnstay Colliery have tanks and they pass theirs through, but I frequently have complaints about them letting it off down into the river.

32807. Do they use that water over and over again in the slack washing process; do any of them do that ?—Oh yes, Sir. This slack washer is self-contained, it is supposed to be, it is to a certain extent. There is negligence on the part of the men very often, and the mine water is used for the purpose of washing the slack.

32808. But I suppose the mine water that is pumped up is a considerable volume, is it not ?—Yes, from some of the pits and some of them are comparatively dry; being hardly any discharge from them. At the Gweryeet Colliery near Wrexham, there is an enormous discharge of mine water which is heavily charged with reddish sediment which is carried down a culvert and empties into the River Alyn, a tributary of the Dee.

32809. Have you had trouble with the mines that pollute the Dee seriously ?—Yes, Sir. Oh yes, that is one of the worst discharges we have of mine water.

32810. Have your Board taken any action in that case ?—We are in communication with the Company now, Sir, and have been for some time. In the last communication I had from them they said that the Manager would put it before their Company at the next meeting and he would take their instructions.

32811. Do they hold out hopes of putting down tanks ?—They hold out no hopes whatever; they do not give us any encouragement whatever.

32812. (*Colonel Harding.*) I would like to ask you, in regard to the last paragraph of your statement, will you say more particularly what you mean. You say there

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are a large number of factories, works and mills that discharge their effluent into the Dee without any attempt at treating it ?—Yes, Sir.

32813. Where, about, on the Dee does this arise ? Well, the Gweryeet Colliery is about 20 miles up from Chester.

32814. What is the particular business that they carry out ?—Mining ; it is all mine work there.

32815. You have told us that the clay-pits do not cause you much trouble and you have already spoken to us about collieries ; I thought this referred to something else. You speak of factories, works and mills ?—Yes, there is the Phœnix Colliery.

32816. Yes, that is a colliery again, but I want you to tell me about the factories and mills that you refer to in this last paragraph ?—There is a large number of factories and mills and works that discharge their effluent into the Dee.

32817. What is the nature of the business that they carry on ?—There is the North Wales Paper Mills, Flint. There is the Holywell Mercers, Flint, that is a silk dye works ; both these give a discharge, especially the paper works.

32818. A silk manufactory ?—Yes. There is the British Glurysoff Manufacturing Company, a silk manufacturing works. They give out a heavy discharge. Queensferry Refining Coal Tar and Pitch Works, these have settling tanks, but the tanks are charged to their utmost and we very often get an overflow there, especially in heavy rains. Dobbin's Manure Works, they discharge a little, but it is nothing that is harmful to fish.

32819. Does the County Council take any supervision at all over this river ?—None whatsoever to my knowledge.

32820. Have you applied to the County Council to communicate with these various persons that you have been telling me about ?—No, Sir. The Fishery Board try to deal with them as far as they possibly can and try to do what they can with the owners and fishermen.

32821. You know the County Council have some powers if they choose to exercise them ; have they exercised those powers ?—Not to my knowledge.

32822. How can you exercise the powers that you have ; what funds have you to go upon ?—No funds whatever.

32823. You have no funds at all ?—No, only from the licences and there is something from the Chester City Council and the County Council.

32824. Then, if you have no funds whatever, you are not likely to bring any strong pressure to bear upon these offenders ?—No, Sir, not at all. The Birkenhead Water Works are about to take up their supply and we have got some compensation money from them. The Fishery Board were really bankrupt previous to receiving this sum.

32825. In the case of the factories and mills that you mentioned, are they situated in towns or in urban districts ? No, Sir ; in urban districts on the banks of the river.

32826. Therefore, in their case. it would not be practicable to turn their effluents into sewers ?—No, Sir.

32827. Have you inquired into that ?—Yes, Sir. There are no sewers round about where these works are situated.

32828. (*Mr. Willis.*) Does the river divide two counties ? —It runs through Merioneth, Shropshire, Cheshire and Flintshire and Denbighshire.

32829. I mean Cheshire is only one side of the river ?—Only one side.

32830. And another county is the other side of the river ?—Yes, Flintshire. Then, Shropshire is only on one side.

32831. So that really if the counties were going to take action, they ought to join together in the matter, because so many counties are interested in it ?—Yes, I should say so. There is Hawardenbridge Galvanised Iron Works situated on the border of the estuary of the Dee, and there is a very large volume of discharge from them and we are frequently having trouble with them, and the Board has done whatever they possibly could, with the owners they have now taken it on to the marsh-land on the landside of the river. Now and again we have a tremendous pollution in the Dee from this works. There is nothing satisfactory about it. The Board have had trouble with this for years now. We had a complaint last week about it.

32832. (*Mr. Tatton.*) In the last paragraph on the first page of your statement, in speaking of stone and slate quarries, you say occasionally an accident has happened whereby a discharge of a noxious nature has got into the river and caused great damage ?—Yes.

32833. What damage did that cause ?—It caused a great amount of damage to the Fish Hatchery Company at Chirk and it practically ruined the river Curiog of fish life at that time. It arose through a large tank being put across a water race and this tank leaked when they put the gas-tar into it and consequently the gas-tar got into the river, and before it could be removed all the fish were poisoned.

32834. It was gas-tar was it ?—Gas-tar.

32835. What works was it from ?—The Glyneeiriog Macadam Gas Tar Works for mixing this new material for roads.

32836. It was not from the stone or slate quarries then ? —No, Sir ; from the mixing sheds.

32837. From this manufactory that was carried on there ?—Yes, Sir, that was so. There is the North Wales Paper Mills, Flint ; they have a great discharge. I think that is all. There is the Mold Tin Plate Works ; this is another manufacturing process where chemicals are used and the whole of their discharge goes into the Alyn without any treatment whatever. The river is red for a considerable distance down.

32838. Is that below Chester ?—No, above. And in consequence of this and other mine water and slack washings, that river is almost depleted of fish life below these works. It used to be an extraordinarily good stream some years ago.

32839. (*Chairman.*) Thank you ; we are much obliged to you.

Mr. C. Y. MOSES, Chief Water Bailiff, Yorkshire Fishery Board, called in ; and Examined.

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32840. (*Chairman.*) You have been good enough to send us this statement ; perhaps you will allow it to appear on our Minutes as it is ?—Yes, my Lord.

32841. *Chairman.*) You will get a copy of it for correction ?—Thank you, my Lord.

HEWENDEN RESERVOIR.

Destruction of Fish.—This matter was first brought to the notice of the Board about the beginning of April, 1911, and from investigations it was found that the source of this pollution arose from stone washings and poison generated by the use of a gas producer engine, which found its way into the water. Samples were taken from the engine waste pipe and the analysis showed that a very large percentage of cyanides, sulphuretted hydrogen, arsenic and other impurities, found their way into the water used in the stone sawing (which also contains lime) and thence into the catch-pits, and thence into the Reservoir which doubtless accounted for the destruction of the fish therein. The quarry is in the occupation of one John Flesher, who, until five years ago, used a steam engine, and at that time replaced it by a gas producer plant, in the process of which he uses coke and anthracite in the production of gas. This waste product from the gas plant finding its way into the catch-pits which are situate upon an eminence overlooking the Reservoir, the ground appears to have become saturated with this solution and any storm quickly carries the whole liquid into the water of the Reservoir. On June 12th, 1911, we had a further report of more fish having been found dead, some perch weighing up to 3½ lbs.

COTTINGLEY BRIDGE.

Destruction of Fish.—From time to time during the last two years it has been reported to us that fish have been found dead in the River Aire in the vicinity of Cottingley Bridge, Bingley. From enquiries and observations we

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find that the Bingley Rural District Council has a sewer coming down the Bradford Road from Cottingley and crossing the river, being syphoned under the river to the sewage farm on the other side. Owing to the varied nature of sewage which contains trade effluents and washings from wool bowls the sewer became choked. In its course, there are several storm overflows and the poisonous liquid so brought into the stream killed the fish in the river. Proceedings were taken against the Council in March of this year (1911), when the pollution was admitted by the defendents, but all the responsibility repudiated, and the case when being heard before the Local Bench of Magistrates was dismissed. Further action is pending by a farmer named E. P. Barker of Cottingley Bridge Farm for injury to his cattle.

Coal-Washings from Collieries.

This is a matter which from time to time has been brought to the notice of the Board by various angling associations. One recently at Dronfield Woodhouse, Derbyshire, viz., the Mickley Colliery Co,. Ltd., whose pit is situated in the Parish of Dronfield Woodhouse, and who for the last few years have washed coal, but recently have taken to washing slag. This was complained about in 1908. They were approached and remedied the evil in some measure, but again in May this year (1911) complaints were made by a local angling society, and the colliery authorities were seen, when they explained that they did not now wash coal, but only slag, and the colliery was gradually closing down owing to it being worked at a loss. The evil seemed to arise from an insufficiency of settling tanks. Undoubtedly it could have been mitigated by a further use of tanks. This still goes on, some 15 tons a day being washed.

Ocre Water in River Don at Penistone.

The above stream is in a rampant state of pollution with ocre water, and totally unable to sustain fish life owing to the excessive quantity turned out by Messrs. J. Hinchliffe and Co., Ltd., Bullhouse Colliery, Thurlstone, Sheffield. The mine water enters the Don at Thurlstone, a village near Penistone, and ultimately finds its way into the larger streams lower down. Also this state of things exists in the River Dearne, on the high side of Barnsley, several collieries being in the vicinity, particularly near Cawthorne. This length of stream is also highly polluted with ocre water, and contains no fish life, until it gets considerably lower down and receives some small streams in its course. At Dunford Bridge higher up the River Don from the last-named point, there is also a stone quarry, which turns in a quantity of stone sawing water from the quarry which has been complained of by Mr. Charles Chapman, of Carlcoates Hall, Dunford Bridge.

The Rivelin and Locksley Brooks.

These two brooks are in a state unable to sustain fish life, owing to the quantity of condensed and dirty waters turned out from the various forges. These brooks are tributaries of the Rivers Don and Sheaf—all in a bad state of pollution. No fish are to be found in the River Don from the point named until near Doncaster, when fish begin to put in an appearance.

Coke Ovens.

Coke ovens are on the increase at the different collieries. Trouble has arisen at different times with them, and in some cases prosecutions have taken place with success. Several have been reported as starting operations, and observation is being kept on them. The Board has twice prosecuted a Colliery Co., at Hemsworth, near Wakefield, for pollutions from their coke ovens. Another is under observation at Manvers Main Colliery, near Rotherham.

River Swale and its Tributaries.

In two or three cases, one particularly (Thirsk) no treatment of sewage is attempted, and almost annually a destruction of fish takes place in the stream Codbeck, a tributary of the Swale in the immediate neighbourhood of Thirsk, which arises from the accumulation of sewage and disinfectants in the drains in the dry time. The first thunderstorm flushes these accumulations out with disastrous effects to the fish.

River Nidd—Oak Beck, Harrogate.

This is a stream immediately adjoining the Harrogate Sewage Farm, which receives a quantity of both treated and storm overflow water from the Sewage Farm. Complaints are frequently being made by the Knaresboro' Anglers' Club as to the nature of the effluents turned out from the above farm. Otherwise, the River Nidd is in a fair state of purity.

River Aire, below Baildon Bridge, where Bradford beck enters, Calder, and Colne, all in the main streams are in a terrible state of pollution, especially in dry times, owing to the vast amount of trade effluents turned into them; although unmistakable signs are to be seen of an improvement in each of these streams, owing to the treatment at the instance of the West Riding of Yorkshire Rivers Board, particularly in some of the smaller tributary streams around Halifax and district, all of which in the higher reaches contain fish, but none can get down into the larger streams owing to the pollution.

River Hull.

This stream, immediately adjoining Hull, is a tidal river, and receives from the various paint, tar and gas works a large amount of trade effluent from the various streams and drains turned into it. There is one particularly, called the Barmstone Drain, the lower portion entering the River Hull being very bad indeed. This stream is locally known as "Tar Drain," being covered with tar and gas washings and other products of gas and tar making. Representations have been made from time to time to the Barmstone Drainage Commissioners who seem to be now in a powerless state to deal with the different offenders. This stream is held up by flood gates and at spring tides, flushed out at low water, when the poisonous liquid is carried down the River Hull with the ebb; then with the return of the tide it is carried miles upwards towards Beverley. Dead fish of all descriptions are to be found for miles. The river in the higher reaches is one of the best all-round coarse fishing streams in Yorkshire. Some improvement has taken place in Barmstone Drain recently.

Road Tar Spraying.

Injury has been done by the spraying of roads by tar near streams, which is liable, when fresh, to be washed by rain into the stream. The Board has had several complaints and dealt with some four cases.

32842. The first place you mention is the Hewenden Reservoir ?—Yes, my Lord.

32843. Where there has been destruction of fish ?—That is so.

32844. Has your Board taken any steps to prevent the destruction continuing ?—We have several times made representations to this man, John Flesher. The last time that he was approached he said that he did not feel disposed to take any measures to prevent it any more than what he had done. Since the first time, I might say that he has put in another pumping arrangement, whereby he pumps the first effluent back again and uses it for the stone sawing which I take it will only concentrate the thing more and more as he uses it.

32845. Are you contemplating taking proceedings or not ?—Well, our present position is that we are going to lay an information which holds good for six months, and if the man does not take some steps to remedy it, then we shall proceed against him. The information must be laid for six months, and then it can be heard any time afterwards.

32846. Then, you are contemplating proceedings against him ?—Yes.

32847. And in the case of the River Aire that you have mentioned you say that a farmer is now taking action ?—Yes, I believe that the farmer has already once recovered some compensation I cannot tell you what the amount is, but it is a fact that he has got something.

32848. But he is taking action again ?—He is contemplating another action. I may say the West Riding Rivers Board have an order against the Bingley Council and intend proceeding against them. Their sewage farm has been in a dreadful state for some years and they do not seem to make any effort to put it in a workable state.

32849. Do you, as a Fishery Board, endeavour to work with the Rivers Board ?—With the West Riding Rivers Board, I might say, we work very harmoniously. The one helps the other very materially. Only at the last meeting of the West Riding Rivers Board the Chairman thanked our present Clerk for the assistance he had given him during the past year.

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32850. (*Colonel Harding.*) There is evidently no object in two bodies undertaking this work ?—Oh, none whatever. I might explain in the first place that we, as a Fishery Board, are constituted for the administration of the Fisheries Acts from 1861 to 1896 and it is only under those Acts that we can act, you see.

32851. But if you have pollutions which are injuring fish, I suppose those pollutions could be dealt with by the other Board ?—By the other Board; that is how we work.

32852. You work through them ?—Through them. Until they kill the fish, the Fishery Board cannot take any action.

32853. I see, but even when they do kill the fish, do you take any action ?—We take action at once.

32854. You take action in consort with the Rivers Board ?—No, independently, Sir. You see the machinery of the West Riding Rivers Board is somewhat cumbersome as compared with ours. We only have to consult a small Committee as to whether we shall take action or not. We can take action within a fortnight, whereas the West Riding Rivers Board must give them notice of their action and it takes perhaps months. The jurisdiction of the West Riding Rivers Board is confined to the West Riding and to waters only that are not tidal, whereas the Fishery Board's jurisdiction extends over the whole of Yorkshire and out to the three-mile limit at sea.

32855. At any rate, you work in a friendly way with the officials of the other body ?—Yes, we work harmoniously.

32856. (*Sir William Power.*) (*In the Chair.*). You speak of slag washing ?—Yes, Sir.

32857. What process is that slag washing; it is new to me ?—Well, it is coal which is screened through several meshes of screen at different times. In the process of getting the coal from the collieries they wash it when it gets into its nut state.

32858. That is washing coal and separating the slag from the coal ?—Separating the slag from the coal.

32859. That is what is meant; I thought it was separately washing slag ?—No, no.

32860. That is what we understand as coal-washing ?—Yes.

32861. In the case of Cottingley Bridge you speak of the varied nature of the sewage which contains trade effluents and washings from wool bowls, causing the sewer to become choked ?—Yes.

32862. What do you think was deleterious to the fish there; were they directly killed by something, do you think ?—They were directly killed by the cracking of what they call the sud, the grease. When the grease is extracted from the wool, it is put into a large bowl and it is cracked, as they call it. It is cracked with sulphuric acid and it is in the escape of that effluent—well it is practically useless to them, you see—into the river direct that kills the fish.

32863. That escapes from the sewer ?—That escapes from the sewer.

32864. And this case was dismissed ?—Yes, Sir.

32865. Proceedings you say were taken against the Council in March of this year ?—Yes.

32866. They were heard before the local Bench of Magistrates and the case was dismissed; do you know why it was dismissed ?—Yes.

32867. Because you could not prove any damage to the fish ?—We did prove that the fish were actually killed on several occasions, but the Bench held that we did not prove that the fish were killed on one particular day. We laid the information, I think, from December 19th to the 24th, between the two dates, and fish were killed between those dates, and the Bench said we did not prove that they were killed on the 26th or the 25th, I am not quite sure which. It was a case of interested parties, I am sorry to say, but that is a very large measure of what we have to deal with in these sort of things.

32868. (*Mr. Tatton.*) You spoke of the waste from stone-sawing works near Dunford Bridge ?—Yes, Sir.

32869. Does that do any damage to the fish ?—Well, the stone washing water, the stone-sawing water, is mixed with lime to prevent the saw itself oxydising the stone and discolouring it. If that is collected in the catch-pit as it usually is, and discharged in a large volume, it will kill the fish; it chokes them in their gills.

32870. It is the lime that does it ?—It is the lime that does it, and the grit. Of course, the more the grit is used then the finer it gets. I do not know whether any of you gentlemen know the nature of the alluvial deposit which comes down the rivers and settles in the estuaries, and goes up and down with the tides. We have a good deal of trouble with that in the River Humber. Our salmon die by hundreds and thousands as they come at this time of the year when the water is warm. It chokes them in the gills; they are not poisoned. It simply renders the membranes that extract the oxygen from the water inefficient, and they die of suffocation.

32871. What is the deposit that settles ?—The alluvial deposit that comes down the rivers, fine limestone and sandstone and dust, and all that sort of thing. There are thousands of tons come down the River Ouse. If you know the length of the Humber, you will understand that in the river there are two tides at once, one coming up and another going down. It never gets away except in the time of freshes and floods owing to the length of the tidal portion of the river.

32872. You mean to say it accumulates there, because there is so little land water ?—It is a very serious hindrance to navigation. At the present time the Humber Conservancy Board have a huge thing on hand to cope with it. The channel is almost unnavigable at neap tides. Only a week yesterday I went up the River from Goole in our launch, and on the evening tide there were six boats fast then. They were stuck there. There is not the water in the channel to carry them; it is only in the spring tides that they can get up.

32873. (*Sir William Power.*) There is one queston I wish to ask you. You spoke of the River Nidd and the Oak Beck at Harrogate ?—Yes.

32874. Complaints are frequently being made by the Knaresboro' Anglers' Club as to the nature of the effluents turned out from the above farm. What are their complaints ? Is the Oak Beck considered a nuisance to the Nidd in any sense or form ?—It is from what we call the storm overflows. You see in storm time, when the sewage farm cannot cope with the quantity of rain water and surface water that is turned on to the sewage farm they let it out in its crude state.

32875. They pass a great deal of the storm overflow water through percolating filters ?—They should do, Sir, but these complaints are that they do not do it efficiently.

32876. Does the Oak Beck come down only in time of flood ?—Well, only of course in storm times. At a time like the present time there is practically nothing to see; it is in a stagnant state.

32877. But is the storm water from Oak Beck more serious and detrimental to angling than the storm water which comes from the Nidd ?—Yes, Sir, when it is collected by the Harrogate Sewage Farm it is, because it brings along with it a quantity of sewage.

32878. The first rush of it would contain sewage ?—Yes, Sir.

32879. I understand if they turned that direct into the Beck—I have been there recently—it is only after the storm has lasted for some time and it is very dilute. I should have thought the Nidd got quite as serious a contamination from other sources as from this partially polluted storm water which is turned in from the works. But do they give any definite complaint as to the effect upon the fishing or what ?—No, they say it renders the water uninhabitable to the fish. The fishing does not yield so well as it used to do; they say they cannot get the quantity.

32880. The whole Nidd will be turbid in time of storm; the whole River will be affected; the fishing will be affected ?—Not in any serious degree. Whatever comes down will be purely road washings and that sort of thing it will not be domestic sewage, because the mills higher up are practically nothing; they are only the flax mills. I do not think there is anything from the higher reaches above Oak Beck.

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32881. Their point would be that the Nidd below the junction with the Oak Beck and as far as the railway bridge, and further, would be seriously affected by the storms from the Oak Beck floods ?—Yes, Sir, towards Scotton and down that way.

32882. (*Mr. Tatton.*) I want just to ask you a question about tar spreading on roads; you mention that in the last paragraph of your *précis* ?—Yes.

32883. You say that your Board has had several complaints and dealt with some four cases ?—Yes, Sir.

32884. What action have they taken ?—Well, they have not taken any action against any of the several councils that have done it; they have simply warned them; as it was owing practically to inadvertence; it was not done with any intention. I can give you the several places if you care.

32885. How do they prevent it ?—Well, they would have to prevent it at the time in particular of doing it, by stopping up the surface drains. Take, for instance, the Bradford Road, between what is known as Nab-Wood and Cottingley Bridge. It is a stiff gradient downwards, and all the storm overflows are on the right-hand side which flow into the River Aire. Several of these communicate with smaller feeders which come down into the River Aire, and these storm overflows run direct from the road and flow just into it, in actual tar. The first of these at Nab-Wood was seriously poisoned some two years ago.

32886. Suppose there is a heavy storm of rain comes on while they are putting down that tar; how would they deal with it ?—The only thing would be to stop up the gullies at once and turn it on to land.

32887. It is bound to go somewhere, is it not ?—It is bound to go somewhere. We ask them to take all reasonable precautions against that sort of thing. There was another very serious one in Silsdenbeck. All these run direct into the Beck within 10 yards of the roads.

32888. (*Sir William Power.*) How long, after the road being tarred, will the stuff from it be deleterious; many days or a week ?—Well, really I should say up to a week. We had another one on the Dore and Totley Road in the Sheffield Urban District Council. It is on the very Beck that forms the boundary between Derbyshire and Yorkshire. They had left a small heap of what I call blue whinstone chippings mixed with tar. The water formed in pools; it got into this Beck and ran down into the River Sheaf and killed a quantity of fish. That was in 1907; that was about the first one we had. I had another matter if you care to hear it—I do not know whether you gentlemen have the time, it would take rather a long time. It is in respect to a case of sewage pollution at Pickering in Yorkshire, which is in the East Riding, where they have no Rivers Board. But it dates right away from 1902 to 1908. I have all the letters and papers; it is a pretty lengthy thing, and if you would care——

32889. We have not called you on the sewage question; it is rather on the particular contamination that we have been dealing with to-day ?—Yes, thank you, Sir; I thought I would just mention it; thank you very much.

Mr. W. Nance Williams, called in; and Examined.

Mr. W. Nance Williams.

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32890. (*Sir William Power, in the Chair.*) You are Mr. W. Nance Williams, and you represent the Phœnix Mines, Cornwall, do you ?—Yes, Sir.

32891. Of what nature are the Phœnix Mines—tin ?—Metalliferous, tin and copper.

32892. And you wish to speak on a number of points which you mention here in your *précis*. Now, as to (1) Pollution of streams can be set up in two ways; one by discolouration and the discharge of solid substances consequent on crushing and treating minerals mined; what have you to say on that ? You are speaking only of mine discharges here ?—Quite so. Is it a fact that this Commission can really apply to the work of a mine, because in connection with a mine there cannot be any question of sewage disposal in the ordinary sense of sewage.

32893. (*Mr. Willis.*) Yes, but this Commission is appointed to inquire into the disposal of trade wastes generally as well as sewage ?—Not merely sewage.

32894. No ?—Quite so.

32895. And mine pollution is one form of trade pollution ?—Well, in the event of mine pollution being regarded as one form of sewage pollution, pollution can be set up in two ways: (1) By discolouration, and the discharge of solid substances consequent on crushing and treating the minerals mined. (2) By mineral in solution, although the water may at the time be perfectly clear. As this is a natural one, it is impossible to remedy.

32896. (*Sir William Power.*) What mineral in solution are you likely to have in a tin mine ?—Not from a tin mine, Sir, but from copper workings.

32897. You may have some sulphate of copper in solution ?—Yes, Sir.

32898. You are speaking of mines generally now, not of the tin mine, the Phœnix Mine ?—Mines generally, culminating more particularly with regard to the Phœnix Mine. Now, in the case of No. (1) form of pollution, that is discolouration and the discharge of solid substances, such pollution is always aggravated, I think, and increased during heavy storms and rains, as on such occasions a water course has to take the deposits of the watershed or basin which it drains and, in many cases, this is exceedingly large compared with any possible discharge from one or two isolated points of industrial operations. May I proceed, Sir ?

32899. Yes, go on ?—In the case of No. (2) form of pollution—in other words a natural pollution—this is supported by the fact that from all grounds carrying mineral deposits, especially undulating ground, such as exists practically everywhere in Cornwall, the natural water courses carry mineral in solution. In this case it may be argued that the working of any mineral deposit would increase this form of pollution. Such does not, however, necessarily apply as it would be detrimental to the best interests of any party operating were they to neglect the saving of such mineral in solution, wherever it occurs in appreciable quantities, as by-products, in the case of copper by precipitation and in the case of arsenic by roasting. No. (3) it is reasonable to assume, and in my experience it is invariably the case, that the owners of a mine would, for the sake of realising the maximum amount of profits, take every precaution to save all of the mineral deposit possible. Any residue therefrom, which might possibly be discharged, could not have been caught and retained in the process of treatment unless the mining operations and the consequent success of the industry was prevented or seriously restricted.

32900. He would be only securing some 2 or 3 or 5 per cent. of the mineral matter, and letting 95 go which is useless to him ?—Oh, no; in that case, Sir, all mining operations would be a huge failure.

32901. But, as a matter of fact, in the case of a tin mine, does not a very large proportion of the mineral matter you draw from the earth pass away, either into subsidence pits or into the stream ?—The average recovery of tin ore is about 68 per cent.

32902. Of the tin ?—Yes, of tin ore.

32903. Six to 8 per cent. ?—Sixty-eight per cent.

32904. You have got a very valuable tin mine ?—Yes; but I say the average recovery values 68 per cent.

32905. (*Colonel Harding.*) Sixty-eight per cent. of what; of the ore ?—Of the contents.

32906. The contents of what ?—The contents of the tin rock mined. Take a certain quantity of tin in a ton of ore, we should expect whatever that assayed. Supposing, we will say, 1 cwt. of tin to the ton, to recover about 68 per cent. of that.

32907. What proportion of the ore would that be 2 per cent. ?—That would be one-twentieth. Taking the case of 1 cwt. of tin to the ton of ore, that would be one-twentieth.

32908. Five per cent. ?—Five per cent. In the event of an assay value of 1 cwt. of tin to the ton, we should expect to recover 68 per cent. of that.

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32909. Of that 5 per cent. ?—Yes, of that assay.

32910. What becomes of the other 95, as the Chairman asked ?—Well, that would be stacked in dumps, in sand dumps on the mine and possibly a little may go away into a stream.

32911. (*Mr. Willis.*) You do not, at your mine, run it all into the stream. What is your mine—a tin mine ?—Tin and copper.

32912. And you keep it back at your mine ?—We take every precaution to do so ; it is to our interest to do so.

32913. Do you pollute the river ?—There is a slight discolouration, if that can be termed pollution.

32914. Do you get any complaints about your river ?—No.

32915. (*Sir William Power*) What is your river ?—We discharge into a tributary of the Lynher.

32916. (*Mr. Willis.*) And no one ever complains about what you discharge into it ?—No, for this reason, that all riparian owners have failed in the case of the Lynher, because this stream has been polluted from time immemorial.

32917. They have brought actions, have they ?—No, no action has been attempted.

32918. They have not attempted, because the pollution has been from time immemorial ?—From time immemorial.

32919. So there is no fishing there ?—Yes, much fishing and, strange to say, the fish like the polluted waters rather than the clear waters.

32920. Do they like the debris from your mine ?—Yes, and I have known fish to be caught in the highly-coloured water from the mines.

32921. Yes the coloured water, but do they like the actual solid deposit that you discharge ?—The question is the actual deposit is very very little compared with the solid deposits from other sources, natural sources from which the river drains. I will deal with that more fully later on in my notes.

32922. (*Mr. Tatton.*) Might I ask a question about the recovery of the 5 per cent. from the total tin ? How do you recover that 5 per cent ? Does the whole 100 per cent. go to the stamps ?—Yes, of tin rock.

32923. And that is ground down to powder ?—That is ground down to powder.

32924. The whole of the tin is ground down to powder ?—Yes.

32925. How do you extract your 5 per cent. from that ?—By mechanical treatment.

32926. Yes, but what is the treatment ?—In the first place by classifying, running over frue vanners and heavy wilfley tables ; machinery adapted for the treatment of the tin ore.

32927. It is not washed out by water at all ?—Oh yes, water comes in in the treatment ; and then the residue of that goes into settling pits, that is further treated in a finer manner and that goes again into settling pits.

32928. But, then the whole of this tin is dealt with by water ?—Yes.

32929. And the 95 per cent. is washed away by water and the 5 per cent. remains ; is that it ?—No.

32930. Well, how is that worked ?—I think, Sir, you are slightly confusing there, if you do not mind my saying so.

32931. Not at all ?—The matter of the 5 per cent. and the 68 per cent. The 5 per cent. represents the supposed value, per assay, of tin ore contained in the tin rock mined, the 68 per cent. represents the proportion recovered in treatment of the total tin values contained in the rock. We practically recover 68 per cent. and the remaining 32 we find in most cases will not pay for treatment. That does not necessarily say that that goes into the river. The residue of that is in the form of sands which are stacked on the mine.

32932. (*Sir William Power.*) We would like to go on now to the local conditions of the Lynher ; what have you to say on that ?—The mineral deposits of Cornwall are invariably intersected by streams and the scene of mining undertakings is in most cases at a considerable elevation above sea level, and again in some cases removed a considerable mileage from any harbour or creek of commercial importance. In the case of the Phœnix Mines, these are situated 18 miles from the estuary of the Lynher, and the latter is approximately another 5 miles from the vicinity of the Plymouth Hamoaze. In this and similar cases very little solid matter reaches a point of any commercial value and importance, and, in the event of the remote possibility of this, such would be completely overshadowed by deposits from other natural causes altogether apart from mining, rendering the water muddy and impure.

32933. Well now, as to the effect of pollution on the fisheries, you were saying just now it had no ill effect so far as your Phœnix Mine is concerned ?—No, Sir, as far as the disposal of waste waters in the Lynher is concerned it is admitted that deposits more or less were made from a very early period. Evidence of this remains in places along the river to-day and is accountable for (I) by the exceedingly large watershed which it drains, and (II) by the very large number of mines at one time operating within the watershed, which operations have, at least, in one instance, continued from time immemorial.

32934. Is it a considerable river at the point where it adjoins your works, the Lynher ?—Oh no, very small.

32935. Small ?—Well, a large brook you might say.

32936. There is no question of fishery in your immediate neighbourhood then, is there on the river ?—Yes, fish is caught within our polluted waters and immediately below them.

32937. (*Mr. Willis.*) You, as I understand, do attempt some settlement on your waters ?—Well, we do.

32938. How do you get this sand, which you sell to builders ; is it deposited in a pit ?—We deposit it in settling pits.

32939 And you run off the upper water ?—The upper water is run off.

32940. Then, you get the sand ?—The solid substance is deposited in the pits and at regular intervals these pits are cleaned out.

32941. At some mines they do not do that depositing you think. At Dolcoath, for instance, they discharge everything into the Red River ; there is no settling pond ?—I think in the case of Dolcoath, it is a fact.

32942. No settling pond ?—For this reason that pollution is recognised there. I believe there is no question of fish and there is a considerable industry below the mines at Dolcoath in working over the sands in the river.

32943. The sand in the river ?—That is so.

32944. I would like to put just this general question to you ; do you think there ought to be different standards according to the nature of the river. At Dolcoath, for instance, at present they are under no sort of obligation to do anything ; they discharge what they like into the river. You, I suppose, are under some obligation, at any rate you do deposit a good deal of your material ; you keep it back ; you do not let it go into the river ?—Yes.

32945. Do you think it is right that some Public Authority should come in and fix different standards according to the different circumstances of the river ?—Not where a big industry should be jeopardised as the result of it.

32946. Supposing you wanted to establish a big industry on a river which is now pure, would you say you are justified in destroying that river ?—It would entirely depend upon the importance of the river, compared with the importance of the industry which would be established there.

32947. May I put this particular point ? Supposing the fishing industry is worth £1,000 a year, and you are going to establish works that are going to produce £10,000 a year do you consider you are justified, in order to make your £10,000 a year, to take away that £1,000, which the man who owns the fishing now gets out of the fishing ?—I should say absolutely.

32948. You are justified ?—Yes, absolutely.

32949. Would you say, in that case, that you should be made to compensate that man for his £1,000 a year fishing which he is losing ? The case I am putting is, that your works are damaging his fishing, and that he is losing his £1,000 a year. You say that inasmuch as the profit from your works is to be £10,000 a year you are justified in killing

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the river, to the extent of that £1,000. Would you compensate that man under your scheme ?—Well, it might be considered as to his net loss.

32950. You do not readily say that you think you should compensate him ?—It might be considered from the point of his net loss, but, if, as a result of setting up pollution in a stream for the sake of establishing an industry, that individual is to have a certain charge yearly, a standing charge——

32951. That might be another individual altogether. The man who owns the fishing might not benefit in any way whatever by the establishment of your works ; he might not be the landlord and get any royalties from you ?—Quite so, That is the point that I am trying to put before you. It might be considered that that man should be paid for his dead loss in one sum, but if that man should desire to have a standing charge every year on any industry, for the sake of killing the fish, it would be a matter which would considerably jeopardise the expansion of any industry. And whilst on this point, I would like to say, Sir, it is not only the company which is operating that industry that gets the benefit of the monies expended, it is the population generally, the skilled and unskilled.

32952. We realise all that ?—Consequently the tradespeople in addition, and also the agricultural classes.

32953. Thank you.—There are just one of two points more I would like to point out, Sir.

32954. It was really my feeling and that of some of the other Commissioners too, that you were travelling over a good deal of ground that we really do not want to travel over ; it was not of much service to us. That is why we are putting some particular questions that we wanted your views on ?—Yes, Sir, very good, Sir.

ONE HUNDRED AND THIRD DAY.

Wednesday, 22nd November, 1911.

PRESENT :

Sir WILLIAM RAMSAY, K.C.B., F.R.S. (*in the Chair*).
Colonel T. W. HARDING, J.P., D.L.
Sir WILLIAM H. POWER, K.C.B., F.R.S.
Mr. F. J. WILLIS.
Mr. R. H. H. KEENLYSIDE (*Secretary*).

ALSO PRESENT :

Dr. A. C. HOUSTON.
Dr. GEORGE MCGOWAN.
Mr. C. C. FRYE.
Mr. G. B. KERSHAW.

Dr. H. FRANKLIN PARSONS, called in ; and Examined.

Dr. H Franklin Parsons.

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32955. (*Chairman.*) You have been Assistant Medical Officer to the Local Government Board ?—Yes.

32956. We have read this Memorandum, and I fancy we all agree with your first statement, that in towns and populous places, where sewers and public water service are available, the use of dry closets of any kind is inadvisable, on grounds both of health and economy ?—Yes.

32956.* It will be useful to put the Memorandum on the Minutes ?—Yes. (*The following Memorandum was handed in.*)

I.—In towns and populous places, where sewers and public water service are available, the use of dry closets of any kind is inadvisable, on grounds both of health and economy.

II.—In sparsely populated rural localities, where sewers and public water service do not exist, the use of dry closets of improved kind, perferably those in which dry earth is used, is generally to be preferred to that of water closets, especially for the smaller houses ; in such places the closet can be placed at a sufficient distance from the house not to cause nuisance and the contents can be disposed of on the land.

III.—The intermediate case of a rural parish or small urban district containing a closely built village with a surrounding agricultural tract is often difficult to deal with in the absence of sewers and a public water supply, as some houses may have little or no space for the proper placing of a closet or cesspool and the disposal of their contents, although the majority of houses may have sufficient space for these purposes. Under the circumstances there is usually strong local opposition to the provision of sewers or public scavenging, since in the present state of the law the cost of these works has to be spread over the whole contributary place, and paid for by many rate-payers who receive no benefit from them. The Board in such cases have rarely seen their way to make an order requiring the Local Authority to undertake the removal of house refuse and the cleansing of privies and cesspools.

Suggestions are offered for amendments of the law to meet the difficulties of such cases.

The introduction of a public water service in a place without sewers aggravates sewage nuisances by increasing the volume of waste water.

The connecting of house drains, especially if conveying water closet contents, to highway drains not constructed or suited for conveying sewage is a source of nuisance and pollution of streams.

I.—In towns and populous places, where sewers and a public water service are available, the use of dry closets of any kind is inadvisable. Statistics have shown that enteric fever and diarrhœa are more prevalent in houses having dry closets than at those with water closets ; and in towns where a dry closet system is in use than in those with a water carriage system. Also the replacement of a dry closet by a water carriage system has been followed by a considerable reduction in the mortality from those diseases (compare Nottingham and Leicester). A dry closet system in which the closets have small dry and impervious—preferably movable—receptacles (pail closets) is less unwholesome than one in which large deep privy middens prevail, but more unwholesome than a water carriage system.

In Nottingham, during the six years, 1905–1910, the average annual number of cases of enteric fever was :

1	in every	45	houses with	midden privies,
1	,,	217	,,	pail closets,
1	,,	376	,,	waste water closets,
1	,,	861	,,	water closets.

Moreover, under present conditions night soil from towns is little valued as a manure ; it often does not pay the cost of carriage, and is frequently disposed of in other ways than on the land. In many towns, therefore, the

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conversions of dry closets (privies or pail closets) to water closets has been pushed forward by the Local Authority on economical grounds; for though where there is a water carriage system the ashes and dry house refuse have still to be collected by hand, the collection and disposal of these matters are easier, less costly and less offensive when they are not mixed with human excrement.

At Blackburn, 1890. 4½ gallons per head per day.

The conversion of dry closets to water closets involves the need for a larger supply of water, and the production of a larger volume of sewage to be treated, but with due precautions against waste, the increase does not appear to counter balance the saving in cost of scavenging.

II.—On the other hand, in rural localities where houses are scattered and have ample ground belonging to them on which the contents can be disposed, the use of dry closets of improved form, such as would comply with the Rural Model Bye-laws of the Local Government Board, is commonly preferable to that of water closets and especially for the smaller houses. In such a locality, sewers and a public water service are not likely to be provided, since the distances between houses would render them inordinately costly. In their absence the use of water closets would involve either private disposal works for the treatment of the sewage, or the use of large cesspools, periodically emptied. It would also generally involve the use of a force pump for raising the water for flushing; or else flushing only by means of water thrown down by hand, which is commonly found insufficient to prevent fouling of the w.c. pan and blocking of the drain. On the other hand, where there is plenty of space a dry closet can be placed in a situation where it will not be offensive to persons in the house, nor risk pollution of the well; and its contents can be utilised on the garden. A cesspool may still be necessary for the reception of liquid refuse, but where it has not to receive w.c. contents it need not be so large, nor will the volume of liquid to be removed be so great.

If an indoor closet be desired an earth closet may be used in place of a w.c., but should be kept supplied with dry earth, and should preferably be entered from the open air under a verandah. Earth closets are very suitable for use in such localities, but genuine earth closets, in which dry earth is used are not often met with though they have recently been successfully used at country schools in Hampshire and elsewhere. What are often called "earth closets" are pail closets in which the material, if any, used to cover the excreta is fine ashes which are inferior to earth as a deodorant and resolvent. The difficulties which have prevented the more general use of earth closets in country places—and still more in towns—are the labour and expense of procuring and drying suitable earth, and of removing the additional amount of material. Moreover, there is no legal provision for requiring that earth closets shall be kept provided with dry earth or other deodorising material, and as there is no material structural difference between an earth closet and a privy—the difference being only in the use of dry earth—it happens that a structure which has been provided under the name of an "earth closet" is in practice used as a privy.

III.—The case—intermediate between that of a town and a scattered rural district—of a rural parish or small "urban district" containing a compact village in addition to a surrounding agricultural tract, often presents much administrative difficulty where sewers and a public water service do not exist. In such a place there may be houses which have little or no space about them on which a privy or cesspool can be placed, at any rate without being objectionably near to the house and well, and many of those in the village proper may have insufficient garden ground for the disposal of night soil or sewage; so that the householders have to get other people to remove these matters from their premises. The farmers may be willing to do so for the value of the material as manure, but generally only at their own time. The farmer only requires the manure at one or two seasons of the year, at change of crops, and he cannot spare his men for scavenging work at harvest time, which is precisely the season of the year when frequent removal is most needed on grounds of health. Hence scavenging by farmers commonly involves large accumulations undesirable on grounds of health in the immediate neighbourhood of houses. Similar remarks apply in some degree to the use of the material by cottagers on their gardens or allotments. Hence in a closely built village a public system of refuse removal is generally needed, and, also, if the village be unsewered, a system of cesspool emptying. The introduction of a piped supply of water, in the absence of sewers, increases the difficulty, leading to the production of a larger amount of waste liquid. The absence of a proper system of sewers, where houses have little space about them, is apt to lead to the following evils, viz.: nuisances from cesspools near houses, especially when neglected and overflowing, or in the act of emptying; pollution of wells by soakage of sewage; nuisances from stagnant sewage on the surface of the ground; pollution of ditches and streams; and discharge of sewage into highway drains constructed and intended to convey surface water only. The latter practice is a frequent source of nuisance, especially if water closet sewage is turned into the highway drains, but there appears to be no legal power to forbid it, or to compel the disconnection of the house drains, even if the connection has been made without the permission of the Local Authority. Nevertheless, in a rural parish containing a compact village, the provision of a system of sewerage, or of public scavenging for the village, always meets with strong local opposition, chiefly on the ground that, while the proposed works will benefit only a fraction of the inhabitants, the whole of the ratepayers have to share the cost, including those residing in the outlying parts of the parish who are able to dispose of their sewage and refuse on their own land. This view is generally endorsed by the District Council, and in the absence of a local complaint under S. 299, Public Health Act, 1875, which is rarely forthcoming, the Local Government Board have no power to enforce the provision of sewerage. They have, however, power, under S. 42 P.H. Act, 1875, to make an order requiring the Local Authority to undertake or contract for the removal of house refuse and the cleansing of earth closets, privies, ashpits and cesspools, but the Board have, in very few instances, seen their way to make such an order in a parish in a rural district, in the face of the strong local opposition, and of the fact that the houses at which such works are urgently required are generally only a minority of the whole.

In order to meet the difficulties I have mentioned it is desirable that Local Authorities should have the power:

(1) To place the cost of sewerage or other sanitary works by special assessment upon the portion of a rural parish benefited by them, without making this portion a separate contributory place for all purposes (Urban Authorities have such a power under S. 211 (4) P.H.A. 1875);

(2) To make a charge to the owners or occupiers of houses at which they undertook the removal of house refuse and the cleansing of privies and cesspools (at present it is held that they have no power to make any charge for the work);

(3) To forbid the connection of house drains conveying sewage or foul liquid to highway drains not constructed or suitable for the conveyance of sewage;

(4) To forbid the construction of water closets in places unprovided with proper sewers or a sufficient water supply, where they cannot be used without causing a nuisance;

(5) To require that every new house erected in a place where sewers and a sufficient water supply are not available, shall have in connection with it sufficient land for the innocuous disposal thereon of the sewage and refuse produced at the house (at present open space can only be required, under bye-laws, for securing the free circulation of air about houses, and the amount of space which can be required for this purpose is not sufficient for the disposal of refuse);

(6) To require that earth closets should be kept provided with a supply of dry earth or other deodorising material.

32957. You state in your Memorandum, that enteric fever and diarrhœa are more prevalent in houses having dry closets than at those with water closets?—Yes.

32958. And in towns where a dry closet system is in use than in those with a water carriage system?—Yes.

32959. Then you also compare Nottingham and Leicester to show that the replacement of a dry closet by a water carriage system has been followed by a considerable reduction in the mortality from those diseases?—Yes.

32960. You give the statistics below here ?—Yes.

32961. In Nottingham, the average annual number of cases of enteric fever was 1 in every 45 houses with midden privies, 1 in 217 houses with pail closets ; 1 in 376 houses with waste water closets, and 1 in 861 houses with water closets ?—Those figures are taken from the Annual Report of the Medical Officer of Health for Nottingham for 1910, which I have here.

32962. Then, have the middens been replaced by water carriage since ?—Where ?

32963. In Nottingham ?—There are not many middens now left, but there are a great many pail closets. I believe that water closets are constructed for new houses, but the Town Council have not seen fit to replace the pail closets by water closets in existing houses.

329640. Then you go on to point out that under present conditions night soil from towns is of little value as a manure ?—Yes.

32965. I presume that means the fresh night soil ?—It means that, under the circumstances of towns, it does not pay for removal. The cost of carriage in populous parts of the country, where the night soil has to be carried long distances in order to find land on which it can be utilised, is so great that it does not pay for the cost of removal.

32966. And I suppose another difficulty is that it could not be utilised continuously ?—No, it can only be done at the time when the ground is suitable for it. Of course, it can be stored. If a farmer has land he can store it until such time as it is required for use, but that is apt, in itself, to create a nuisance. I may perhaps read an extract from a Report which I made to the Board in 1892.

32967. If you please ?—That was a good many years ago, but it would apply, I believe, still more at the present time. "In the towns visited by me, the dry systems of excrement removal, besides their offensiveness, have not only not realised the hopes of profit which were at one time entertained, but have proved in practice very expensive in working, while on the other hand, the works of water supply, sewerage and sewage disposal which have of late years been carried out have afforded increased facilities for the extension of the system of water carriage. Again, owing to the growth of population in the larger towns and the depression of agriculture, the demand for night soil, relatively to the supply has lessened ; * while in many places ashes and dry refuse are found so difficult to dispose of that they are got rid of by burning them in 'destructor' furnaces, a process which the presence of night soil renders more difficult. These circumstances have tended to render it desirable, even from an economic point of view, to separate the excrement from the solid refuse of a town, while the sanitary advantages of its rapid removal have become more generally recognised." I may say that the common method of getting rid of town refuse is to tip it into quarries and other empty places. Round London and in the South it is used for brick-burning sometimes, but in the North, where there are excavations, such as quarries and clay-pits, it is often tipped into those. And another way—in places on the coast—it is barged out to sea. I believe, at Liverpool, there is a hopper-barge which barges it out to sea. In other places, some Lancashire towns, the excrement that is collected in pail closets is got rid of by being tipped into the sewers. A manhole in the sewers is opened and the pails are emptied into the sewers, so that the excrement is carried away by the sewers. But, of course, it has the disadvantage of being stored for some time in the neighbourhood of the houses.

32968. Are these sewers specially constructed for sewage, or are they ordinary road sewers ?—They are sewage sewers, in that case.

32969. In the towns it is obvious that it is very difficult to dispose of night soil. You go on to state that the conversion of dry closets (privies or pail closets) to water closets has been pushed forward by the Local Authority on economical grounds ?—Yes.

32970. For the collection and disposal of these matters, are sewers less costly and less offensive when they are not thus accumulated ?—Yes, I can give you reports which show that that is so. One reason for it is that the excrement, as its name night soil implies, is commonly collected at night, because to remove it in the day-time is a very offensive operation. But the night removal is also offensive, because it leads to the soiling of the ground if it is not properly supervised. But where a water closet system is adopted, dry ashes and so on can be removed by a pail system ; it can be put in pails.

32971. It is not offensive ?—And the cart goes round from door to door and has to take them up and empty them.

32972. It is not offensive ?—It is not offensive in anything like the same degree, and it is much less laborious, much less objectionable to the men. It is difficult to get men now to scavenge the middens of the old times, in consequence of their objection to this class of work.

32973. Then, of course, more water is required for water closets than the dry closets, and there is a larger volume of sewage ?—Yes.

32974. But you say the increase does not appear to counter-balance the saving in cost of scavenging ?—In the report I have mentioned I gave some figures showing that the amount of water required for water closets was about seven gallons per head per day, and, of course, that would mean a corresponding increase in the volume of sewage.

32975. You give the facts as regards Nottingham for the outbreak of enteric fever in houses with midden privies, but is there any reason for it ; is it because the enteric fever spread more readily owing to midden privies or pail closets than it can with water closets ?—The facts seem to point it out, and, according to modern views, the agency of flies is a very important one. Flies settle upon the human excrement and then they fly in the houses and settle on food and convey the bacillus in that way.

32976. I suppose, if the excrement were covered, the flies could not get at it ? Are those midden privies used without earth ?—Oh yes, you could not furnish a supply of earth to a town.

32977. That would be a very difficult thing, of course ?—But I may say that earth closets themselves are very much blamed in India for the spread of typhoid fever ; it is held that covering with earth is not sufficient to prevent the access of flies.

32978. I think we are all agreed that in towns it is impracticable to use anything in the shape of the dry closet system ?—Yes.

32979. But you speak of rural localities, where houses are scattered ?—Yes.

32980. And you recommend the use of dry closets of an improved form, especially for the smaller houses there ?—Yes.

32981. Have you experience of that ?—Oh, yes. I have had one in use in my own house many years ago, when I lived in the country, and I stay at houses sometimes where they are used.

32982. What became of the excrement ?—It was dug into the garden.

32983. And was the material, after nitrification, used again for the same purpose ?—I had a garden where I could get fresh earth. It can be so used, but it was more convenient to get fresh earth than to dry the earth that had been used once.

32984. Was there much difficulty in disposing of it ?—Not in the case where I had a garden ; it was merely to carry it into the garden and dig it in.

32985. And no trouble with the gardener ; he did not object to do it ?—No ; I was generally my own gardener at that time.

32986. Then, did you find any better yield by using this stuff as manure ?—I cannot say that I observed any very great manurial effect from it, but I noticed that a good many weeds came up where it was dug in.

32987. I suppose, in country districts, water closets would be impracticable, owing to the fact that the drainage system would not be connected ? You could not have a special drainage system for each country house ?—For the larger houses you could, where expense was not an object. A rich man, who is building a large house, would desire to have water closets inside for the use of his guests

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* Another reason for the lessened demand for town refuse by farmers is the large admixture which it is found to contain of tin cans and other similar matters worthless as manure, owing to the increased use of tinned meat and other preserved provisions.

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who come from towns and are not accustomed to earth closets, and also for the greater convenience and cleanliness, and he will not mind the expense of pumping water to a cistern at the top of the house and of a system of disposal of sewage.

32988. Then, there are more cesspools, are there not?—Not necessarily, because, as the Commissioners know, there are other methods which can be used on a small scale—septic tanks and filter beds, irrigation and so on. A wealthy man in building a large house would prefer to go to the expense of a system like that for the greater convenience and cleanliness of the water closet system. But in the case of cottages that is not so, and cesspools there are liable to become a great nuisance. Of course, in cottages in country places where there is no water supply laid on, if water closets, or closets connected with a drain, are adopted, they have to be flushed by pouring down water by hand; and the amount of water which is used, where it has to be pumped by hand or raised by a windlass, is comparatively small, and the amount of flushing is often not sufficient to keep the pan clean, and to keep the drains from being stopped up. So that, in cases where there is no public water supply and no public sewers, I should not advise the use of water closets for the smaller houses, if there was ground on which another system could be used.

32989. Then you recommend the dry closet under such circumstances? But the cesspool might still be necessary for liquid refuse, might it not?—Some means of disposing of liquid refuse would still be necessary.

32990. Bath running, for example, the parings of turnips, potatoes and cabbages and so on; these liquors are very fermentable?—Yes.

32991. Would they not just be thrown on to the garden?—They could be thrown on to the garden. If people would take the trouble, they can be disposed of on garden ground without creating any nuisance. They are very good for fruit trees. They might be thrown among the fruit trees, or a hole could be made in the ground, and they could be poured in and covered over with earth. They can be disposed of in that way, without drains, if people will take the trouble, but the majority of cottagers will not take the trouble.

32992. What becomes of them?—As a rule they simply throw them out of the door. Sometimes they throw them out of the front door and they go into the street drains. Sometimes they are thrown into the ashpit; where the midden privy system is in vogue, that is a very common way of disposing of them. In the south of England, in some parts of Essex for example, they have what they call "bumby-holes," that is holes dug into the garden where all the household solid refuse is put and the slops are poured upon them and there they accumulate till they are wanted in the garden for manure.

32993. You mean excreta also; the whole thing?—No, not the excreta; they generally have vault privies for the excreta.

32994. Is there any difficulty in providing earth for such dry closets in practice; anything special I mean?—Where there is no garden, of course there is.

32995. Of course, but has the earth to be anything special; has it to be dried or treated in any way before it is used?—Yes, it should be dried.

32996. Is not that rather troublesome?—Yes.

32997. How could that be done?—It can be stored in sheds. It wants a shed or some covered place to store it in. It is difficult to get earth of the best kind. The best earth is that from cultivated ground, which contains the nitrifying bacteria, but very commonly ashes are substituted for earth. Ashes which have been incinerated, of course, do not contain these bacteria, and though the ashes covering up the excrement to some extent mitigate the offensiveness of it, they have not the same nitrifying and resolving action which the earth, with its natural bacteria, has.

32998. You say, they are not very often met with, genuine earth closets?—No; I think they are more in use in the south of England, in Hampshire and in Dorsetshire, the part of the country where they were first introduced, than elsewhere. I could give you, perhaps, the names of places where the system is in use. At Wimborne, the Local Government Board sanctioned in 1883 a loan for the purchase of land for the supply of earth to earth closets, but I do not know whether that is still carried out or not. But what we frequently find is that what is called an earth closet, and which has perhaps been erected as an earth closet, becomes in practice merely a privy owing to earth not being used in it. You can hardly say there is any structural difference between the two; the difference is a matter of use, and the Public Health Acts do not give any power to require an earth closet to be kept provided with earth. Bye-laws can be made to require a closet to be kept supplied with water for flushing, but not to require an earth closet to be kept supplied with dry earth.

32999. Is there any means to compel people to use earth closets, or are they left entirely unfettered as to the method of disposing of their excreta in the country districts?—The Public Health Act, 1875, under Sections 35 and 36, requires that every house should be provided with privy accommodation; but, except so far as it is regulated by Bye-laws, the law does not prescribe what kind of accommodation shall be provided. In districts where the Local Authority have made Bye-laws, they may prescribe the construction of water closets, earth closets, privies, ashpits and cesspools. They cannot say whether it shall be a privy, or an earth closet, or a water closet, but a person who constructs a privy, an earth closet or a water closet must construct it in accordance with certain conditions which are laid down in the Bye-laws. I have here a copy of the Board's Rural Model Bye-laws which contain clauses on these subjects.

33000. Then, is there any machinery to see that the conditions are complied with; are they inspected?—It is the duty of the Local Authority to see that the building is constructed in accordance with the Bye-laws.

33001. And use; that is the question?—The Bye-laws have nothing to do with use. As I said before, there is no power to compel the use of earth.

33002. Then, it is a pure educational matter?—Well, if there is a nuisance; if the closet is allowed to get into such a state that it is a nuisance, then the Authority can deal with it as such.

33003. If it is a nuisance to their neighbour, not necessarily to themselves? They must be willing to stand the nuisance and say nothing, but if a neighbour complained, the Inspector would be called in?—Please see the terms of Section 91 of the Public Health Act, 1875.

33004. (*Mr. Willis.*) That says: "(1) Any premises in such a state as to be a nuisance or injurious to health—— ?—That might be to their own.

33005. (2) Any pool, ditch, gutter, water-course, privy, urinal, cesspool or ashpit, so foul, or in such a state as to be a nuisance or injurious to health"?—Some difficulty has arisen, I believe, as to the meaning of the word "or," whether it means "and." It was at one time contended that it must be proved that the nuisance was actually injurious to health, but I believe now it is held that it is sufficient that it is a source of potential injury, and that it is not necessary that actual injury to health should have arisen from it before it can be mitigated.

33006. Is there any tradition among the cottagers or the people who live in those small and isolated cottages as to what they ought to do, or has any tradition entirely died out? There was a tradition at one time as to the method of disposing of this in the gardens; has it died out? The point I wish to make is this; for instance, in China the population regard their excrement as a valuable asset?—Yes.

33007. And I suppose they would regard it as a gross waste to dispose of it in any way, except for the cultivation of crops and so on. That must have been a very old tradition in the country; is there anything of that kind here?—No. Of course, in China labour is very much cheaper than in this country.

33008. That is true?—And people are not so particular, I expect.

33009. About smells?—About smells, and things of that kind.

33010. Probably not, but still, even admitting that, it appears to me that something educational might be done in order to teach people the right way of disposing of sewage. Does it not very largely come on the women folk, rather than on the men? They naturally have to do with the cleaning of the house and the cleaning of the privy?—Well, they might with keeping the seat clean, but not with the emptying of it; it is not at all a woman's work.

33011. Well, they do it, you know, in France?—I may say that in isolation hospitals, in some cases, earth closets have been used, and they have been found to be very unsuitable for them. One reason is this, that in a place that is largely used by women there is a great deal more urine in proportion than there is in one used by men, and, therefore, it involves very much more earth, or other absorbent to keep the place dry.

33012. You know, it is always regarded as the duty of women to remove the urine in an ordinary house. I suppose in their own house, does not that include the removal of excrement at the same time?—Not from the privy; not the cleaning out of the privy, or of a pail closet.

33013. It always occurs to me that it is rather a woman's work. If she keeps the house clean, this being part of the house, this ought to be kept clean. It is a matter of opinion, of course. I was wondering whether any education had been given to girls in house sanitation, in point of fact?—I do not think, Sir, you would find your housemaid take that view.

33012. Possibly not. Now, we come to the third case, the case intermediate between that of a town and a scattered rural district, a small urban district. I suppose there is very great difficulty there to know what to do, where there is no garden space, where there is no supply of earth, and where the population is not rich enough to stand the cost of a regular water supply and drainage system?—Well, the difficulty is often this, that these works are only required for a small part of a large contributory area, the greater part of which can do without them, and the people in the outside part of that area object to pay rates for providing works for the closely built part, works from which they get no benefit themselves.

33015. And what is usually done under the circumstances?—What is very often done is that the whole thing drops through, because of the opposition of the outside ratepayers.

33016. But I mean as regards the collecting of night soil; do they use dry closets, as a rule, and are there arrangements made for collecting it?—Of course, under these circumstances, makeshifts of some kind have to be adopted. What is most frequently done, I should say, is that pail closets were used under those circumstances.

33017. And removed by some person?—It may be that the man has an allotment outside the village and he uses the contents from time to time there.

33018. Carries it?—Yes. Or it may be that a farmer will take it at certain times, but the difficulty with farmers, and to some extent with allotments, is that the stuff is not wanted all the year round, but only at change of crops, and also that at the time when its removal is most imperative on the ground of health, the farmers' men and the cottagers themselves may be busy with getting in their crops, and they cannot spare the time.

33019. I suppose you have read Dr. Poore's Book on "Rural Hygiene"?—Yes.

33020. You remember that he found that the night soil could be dealt with the whole year round, by trenching it and leaving it till it was wanted?—Yes.

33021. Is it not merely a question of systematisation, and is the neglect of these precautions, these methods of dealing with it, not merely want of education?—It is partly no doubt want of education, but it is also that people will not take the trouble. It is not worth the time and labour which it involves.

33022. May I just give you a parallel case? There is no law to compel people to keep their faces clean?—No.

33023. And yet, as a rule, they do wash their faces, because they would come under the contempt of their neighbours if they did not. Most people wash their faces, unless they wish to be regarded as abandoned characters. Would it not be possible to introduce a similar feeling that there is want of propriety in not keeping that domestic part of their work as capable as anything else?—It is not so obvious to their neighbours as a dirty face.

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33024. That is perfectly true, but still there is the smell from it?—And also it is a more laborious and unpleasant operation.

33025. If it were regularly done, I do not think it need be very troublesome. Do you not think there is some possibility of educating the people to see that this is not merely a valuable substance, but also a nuisance, if not disposed of; and seeing that, according to Dr. Poore's lines, so much can be gained from it?—I do not think there is much chance of educating them to that under present circumstances. It seems to me the present tendency is rather the other way, that people object more and more to do anything that involves individual labour and responsibility, and they wish to throw more and more upon the Public Authority. I have heard that difficulties have arisen on that score at the Garden City. People go there, who have been accustomed to live in towns where the refuse has been collected by the Public Authority, and they object to the labour and trouble of disposing of it themselves on their own gardens. They expect it to be removed as they are used to in the towns.

33026. It is rather to be regretted that that is so. Then you speak of the absence of a proper system of sewers—where houses have little space about them—apt to lead to a number of cesspools near the houses?—Yes.

33027. And the number of the cesspools near houses, especially when neglected and overflowing, or in the act of emptying; pollution of wells by soakage of sewage; nuisances from stagnant sewage on the surface of the ground; pollution of ditches and streams and discharge of sewage into highway drains constructed, and intended to convey surface water only. Now, does this press greatly on the population; is this nuisance frequent?—Yes, it presses greatly where there are no sewers. But they often put up with it, or adopt palliative measures rather than go to the expense of sewers.

33028. What is your private view of the matter, as to what should be done in a case of that kind, because it appears to me there is the real difficulty in those semi-populous districts?—My private opinion is this, that in the case of a compact village, with a large rural area within the contributory place, a small scheme might be allowed for the village alone, and that the law should give the means of charging the cost of this upon the area that is benefited by it. But in the present state of the law, it can only be carried out at the cost of the whole contributory place and that causes a great deal of opposition, so the works are not carried out; or, on the other hand, it may be contended that if everyone in the parish has to pay, everyone in the parish ought to have the benefit, and so larger works are proposed and carried out at, of course, a much greater expense than it needed. The cost of the works depends very much upon the distance that the houses stand apart from one another.

33029. Naturally?—If the houses are close together, the cost will be comparatively small; if the houses are a long way from one another, it means a long length of pipe to connect them together. Perhaps I might put in a Memorandum which I wrote for the Local Government Board on "Legal Difficulties Impeding Sanitary Administration in Rural Districts." It was for Office use only, so the sanction of the Board should be obtained before it is made public.

33030. Then you would suggest that power be given to a rural parish, such as is possessed by authorities, to rate a certain number of the dwellers in that district?—Yes, to the Rural District Council to rate them for the works from which they exclusively benefit. It might not, perhaps, cover the whole of the works, but if the people benefited by them bore the main cost, the opposition from outside ratepayers would be much mitigated.

33031. Then, what would you suggest should be done with this water-carried sewage, because a small community like that cannot afford means of purification such as septic tanks or a purification system?—Of course, that would depend upon the circumstances of the locality, and more especially on the amount of fall that was available and the presence of suitable land.

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33032. That involves the acquiring of land by that locality ?—It would involve, of course, the acquiring of land, in any case, but the particular system to be adopted would depend upon the circumstances of the case.

33033. Would you leave it to the Rural Authorities entirely to determine what should be done with the sewage ? They would require to get some costly advice. Would you have that done by a Government Department ?—I should propose to leave it to them, in the first instance. Of course, if a loan were required, a local inquiry would be held by a Government Inspector, before whom the merits of the scheme would be gone into.

33034. As they are in other cases ?—As they are at present, but a small scheme could often be carried out by local means, without involving a loan, just to provide for a few closely built houses. The point I should like to make is, that there is no power, in the present state of the law, to prevent that state of things arising *de novo*. In a village, where there are no sewers, or no public water supply, a man may buy a small plot of land and erect a row of cottages upon it without more open space about them than is required under the Bye-Laws for securing a circulation of air. There is no power to require him to provide an additional amount of land in order to dispose of his refuse upon it.

33035. I see ; and you think that power should be given ?—I think that power should be given ; I think you will find it in that Memorandum.

33036. Well, you say it is desirable that Local Authorities should have the power to place the cost of sewerage or other sanitary works by special assessment upon the portion of a rural parish benefited by them, without making this portion a separate contributory place for all purposes ; and to make a charge to the owners or occupiers of houses at which they undertook the removal of house refuse and the cleansing of privies and cesspools. (At present it is held that they have no power to make any charge for the work) ?—That is the view that is held at the Local Government Board.

33037. But do they not employ voluntary persons to empty their cesspools ?—If they can get them, but the charge is often very high. I can give you, perhaps, some instances of the cost of cesspool emptying. At Caterham, the cost worked out in 1900 at 12s. for each cesspool emptied, or 1d. for every 11·7 gallons removed. In another case, where there was a leaky cesspool, the cost of emptying was 1d. per 2½ gallons removed.

33038. Can you give me any idea what proportion that bears to the population ? Would it come heavy upon the population in the district to have their cesspools emptied ?—At Caterham, a place of [in 1901] 9,486 inhabitants, it cost £832.

33039. About 4s. an inhabitant ?—I should have to look up the population at the time I refer to, but it was then only a small place. By the pneumatic cart, it cost 5s. per load in one case.

33040. Is there any provision to make those people agree to combine to pay this sum ?—No. They may voluntarily agree to do so, and I daresay sometimes people do, but it can only be done by the Local Authority at the cost of the whole contributing place. In Staines Rural district, emptying of cesspools by pump and hose cost 5s. 6d. for a cesspool of 300 gallons ; 3s. 6d. per load for one of 750 gallons capacity, the load being 300 gallons ; 1s. 9d. per load for one of 3,000 gallons. The cost of emptying a 1,000 gallon cesspool quarterly worked out at £2 per annum. A cesspool of only one load capacity, that is 300 gallons, would cost £3 6s. per annum. A good deal of the cost is for opening the cesspool and getting the apparatus there and so on.

33041. Yes ?—At another place, by a pumping system, the cost was from one-eighth to one-tenth of a penny per gallon.

33042. All that is a very considerable cost to the inhabitants ?—Yes. At another place, emptying 172 cesspools cost £265 a year.

33043. Supposing they do not do it, what happens ?—Well, nuisances arise, of course.

33044. And then, they are made to ?—They overflow.

33045. The whole community is charged probably ?—If a nuisance arises, the occupier or the owner, the person by whose default it arises, may be compelled to abate it, and he has to do that at his cost.

33046. You suggest that a charge should be made to the owners or occupiers of houses at which Local Authorities undertook the removal of house refuse and the cleansing of privies and cesspools ?—Yes.

33047. Then, you would also forbid the connection of house drains conveying sewage or foul liquid to highway drains ; that is obvious too ?—I would forbid that.

33048. Forbid that ?—Give the Local Authority power to forbid. I think it has not at present. I believe it has been found difficult in practice to prevent it.

33049. Then, you would forbid the construction of water closets in places unprovided with proper sewers, or a sufficient water supply where they cannot be used without causing a nuisance ?—I would give the Local Authority power to forbid it, unless means were provided for the innocuous disposal of the sewage. Of course, if a man put up a private installation of his own, I would not forbid him to have a water closet, but in places where there was no such private installation, and where the water closet was likely to become a nuisance, then I would. The converse power is given in Section 39 of the Public Health (Amendment) Act, 1907. In places where the Local Authority have provided sewers and a sufficient water supply, they can forbid the erection of privies ; they can require that water closets should be made.

33050. Really does not that press hard upon certain people who can dispose of their own refuse perfectly well without utilising the water supply ?—No, because it is optional upon the Local Authority to do so. But, as a matter of fact, where sewers and a water supply are available, people generally prefer to use them, rather than have any form of dry closet with the nuisance and labour which it involves.

33051. Then, you would suggest that each house should be provided with a sufficient amount of land for the disposal of its sewage ; that is, when a water supply is not available ?—Yes.

33052. You spoke of that before ?—Of course, it might be necessary to have some power of appeal in cases like that to the Local Government Board or someone, that the order of the Local Authority was not unreasonable.

33053. Interpret the word "sufficient" ; a sufficient supply of land ?—Yes, I would not say how much. It would depend on the size of the establishment, the nature of the land and other things.

33054. If earth closets are used, for instance, they should be kept provided with a supply of dry earth or other deodorising material ?—I think that would be necessary.

33055. Now, who would again see that that was done ; some inspector to go round ?—I suppose the Inspector of Nuisances ; it would be his duty to see that that was done.

33056. He would not wait till a nuisance arose ?—He ought not to.

33057. Is there anything you would like to add to what you have told us ?—I think I have said what I wished to say.

33058. We are very much obliged to you. I am sure the Commission is greatly indebted to you for giving us the time and taking the trouble to give us the information on the subject ?—I am a man of comparative leisure ; I have retired from the Board. I shall be pleased to put in either of these Reports.

33059. I think they would be very useful ?—If they would be useful, I think I would call attention to the preface to the revised model Bye-laws as to the removal of house refuse and cleansing of earth closets, privies, ashpits and cesspools, and also to the requirements in the rural model Bye-laws as to earth closets and privies in connection with buildings.

33060. Are these confidential ?—No, they are not. I merely put them in for the information of the Commission.

Dr. H. Handford, County Medical Officer of Health for Nottinghamshire, called in; and Examined.

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33061. (*Chairman.*) You are the County Medical Officer of Health, are you not, of Nottinghamshire ?—Yes.

33061.* You have sent us a statement and I think it should go on the Minutes ?—Yes. (*The following statement was handed in.*)

I would begin my remarks by assuming that all Medical Officers of Health are agreed that the water carriage system of excrement removal is the best practical method at present known where it is available.

For general adoption it necessitates a public, constant and abundant water supply. Having that, a sewage disposal scheme becomes necessary whether the water carriage system of excrement removal be adopted or the conservancy system. The discharge from water closets does not increase the strength of sewage, but dilutes it and does not increase its offensiveness though it does add to its quantity. In Nottinghamshire some villages with as few as 250 inhabitants have adopted a sewage disposal scheme because of the offensiveness of the sewage, though there are only three or four w.c.'s in the village. Almost all villages already possess some system of drainage however imperfect. The use of water closets makes little difference to the need of treating the sewage. It is the increase of volume following the introduction of a public water supply which necessitates the expense of a sewage disposal scheme.

Water closets are being used in increasing numbers for cottage property both in urban and rural districts, without difficulty, and without misuse or damage. They are used for all schools where there is a public water supply. That the water carriage system is adapted for the use of a working class population (including colliers), both in town and country districts, has been shown beyond dispute.

It would be an injury to public health to advocate any system of excrement removal which would discourage the need for acquiring a public water supply. In many towns and villages where the public water supply is insufficient for sanitary purposes, or where there is no public supply, conservancy methods are in use.

In many of the urban districts where there is an abundant water supply the pail closet system was adopted many years ago and the expense of changing it is too great to be undertaken all at once. In such districts no new cottages are fitted with pail closets.

Properly equipped earth closets are practically unknown in this county. The soil is chiefly a very stiff clay and is unsuitable. In the few places, chiefly schools, where an attempt has been made to systematically cover the excreta with dried soil or ashes the experiment has been a failure, and has been discontinued.

In the larger urban districts where pail closets are in use and where they are emptied by the Sanitary Authority's staff there remains the difficulty of disposal of the contents. They are unsaleable, though sometimes the farmers at certain times of the year will take them for the carting. Usually a "tip" has to be established which soon becomes a rat infested mass of filth and a nuisance and danger to the immediate neighbourhood. The spread of enteric fever from such heaps of filth is very strongly suspected, if not actually proved. The spread probably takes place through the agency of dust and flies. The discovery of "enteric carriers" shows that infective enteric excreta cannot be excluded from such accumulations. The most that can be done is to destroy the excreta of acute cases *after diagnosis* and until convalescence is well established. Bitter complaints are made to me of the nuisance from night soil refuse brought into country districts from the adjacent large towns. There have been some limited outbreaks of enteric fever attributed with much probability to this source, and also, with less justification, outbreaks of sore throat.

There have been numerous instances where I have been unable to come to any other conclusion than that the local and continued spread of enteric fever has been due to the action of flies passing from the contents of pail closets to neighbouring pantries or food supplies.

In towns where the emptying of pail closets is carried out by contract, and they are numerous, there are frequent complaints of the irregularity and inefficiency of the service. It is seldom that there is any cleansing or disinfection of the pails.

In smaller communities where the emptying of the pails is left to the tenant, or to the goodwill of a neighbouring farmer, the inefficiency is striking. No new schools in this county are provided with privy-middens, but in the numerous instances where there is no public water supply pail closets are provided. The difficulty of getting them properly emptied and kept in a decent state is a constantly recurring one, and does much to degrade the character of the children.

The difficulty of getting rubbish destroyed, of preventing accumulation and of obtaining any semblance of cleanliness and tidiness is greater in country villages than in towns; and is prejudicial to the character of the inhabitants. It is an additional reason against encouraging conservancy methods. My experience has taught me that, as seen in practice, any conservancy method is at best only a necessary evil, and should only be tolerated where sufficient water for the water carriage system is not available.

In Nottinghamshire sufficient water could be supplied to every village, if a determined effort were made.

The population of the administrative county at the census of 1911 was 344,135.

There are twenty-six sanitary districts held by twenty-four Medical Officers of Health, and they are practically unanimous upon the advantages of the water carriage system and the constant difficulties, dangers, and nuisance of the conservancy system.

In the very short time at my disposal I have not been able to obtain returns from all the twenty-six districts; but in twenty-three districts there are approximately:

Inhabited houses - - - - -	69,573
Water closets - - - - -	21,640
Pail closets - - - - - -	23,163
Privy middens - - - - -	23,876

33062. I think we are agreed, all of us, as you have heard already no doubt, that in populous districts there is nothing for it but water removal of sewage; but the question turns up in rural districts as to what can be done. Well, you state in your *précis*, that water closets necessitate a public, constant and abundant water supply, but that in Nottinghamshire some villages, with as few as 250 inhabitants, have adopted a sewage disposal scheme, because of the offensiveness of the sewage, though there are only three or four water closets in the village ?—Yes; I think there are some of smaller population than that which have found it practicable to adopt a sewage disposal scheme.

33063. With water closets ?—Yes.

33064. Do they flush the water closets themselves by hand ?—Yes.

33065. Then, what becomes of the sewage; does it go into a ditch or into a cesspool ?—In the two places that I have in my mind it goes through small purification works.

33066. Actual continuous filters ?—Yes; a septic tank and filters worked by sprinklers.

33067. And then, I suppose, the effluent is fairly pure ?—Yes.

33068. It runs into some brook or other in the neighbourhood ?—Yes.

33069. Can that be done with advantage by even such a small population as 250, or something of that kind ? I should have thought it would have been very expensive ?—The scheme I have mentioned here for 250 persons has just received the consent of the Local Government Board, and it will be carried out in the course of the next few months. I cannot say how it will work.

33070. Are there rich inhabitants in the village ?—Very few. Well, practically none; the clergyman, I think, is the most substantial man. But my point is, that the nuisance is as great whether there are water closets, or whether there are not. Soap-suds are most offensive

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and are produced by every householder. Each household in that village, with very few exceptions, must wash at home. The soap-suds, if they are thrown into the drains, are more offensive than anything else ; so a sewage disposal scheme becomes necessary, quite apart from whether there are water closets or not.

33071. Is it not possible to adopt the old-fashioned plan of throwing the soap-suds out on the ground ?—There are a great many cottages in the old villages that have no garden whatever.

33072. That involves carrying the water long distances ?—They throw it out.

33073. On the street ?—Yes.

33074. And they go into the road-drains ?—Yes.

33075. Is that any disadvantage, going into the road-drains ?—It goes into the nearest brook.

33076. The actual soap-suds do not appear to me to be very formidable, the constituents of soap-suds, unless added to them there is water in which cabbages have been boiled, and things of that kind ?—The soap-suds break up into fatty acids which are the most evil smelling substances conceivable ; volatile fatty acids from the soap are extremely offensive, apart from the organic matter derived from the bodies, clothing, or floors the soap has been used to cleanse. Urine is also generally disposed of in the same way as the other "slops."

33077. Naturally in this case they would be, and they would make a smell. Then, you think the only thing is to educate the public to a water closet system, and to introduce it, as far as possible ?—That is very strongly my view.

33078. On the other hand, it surely is wrong if we could begin *de novo* and could manage things correctly. We are throwing away an enormous amount of nitrogen every year which ought to go on to the soil, and which formerly did go on to the soil, and which, in many other countries, does go on to the soil, greatly to the prosperity of their agriculture. Do you not think it is a wrong principle ?—I do not feel quite qualified to give any strong opinion upon that point. It is more a question of political economy. But we are producing such an enormous amount of nitrogen, in the form of sulphate of ammonia from the gas works, that an abundant supply of nitrogen is available for agricultural purposes.

33079. We are actually throwing away nearly double as much in excrement as we get out of the gas works ?—Indeed.

33080. It is going to be a very serious question indeed as regards nitrogen, how we are going to keep up the supply. Of course we are going into other questions now altogether ; questions for a century hence ?—From that point of view, I can corroborate Dr. Parsons' statement that the contents, of not only the pail closets, but the privy middens, is unsaleable.

33081. Unsaleable ?—Yes. I have obtained the details only a few days ago of a community of 20,000, where almost the whole of the houses are supplied with privy middens. The Local Authority have a large staff of men and carts for emptying the middens. The farmers pay 1s. to 1s. 4d. a load for the contents of the middens to be carted to them a distance of half a mile to three miles ; so they may pay 1s. to 1s. 4d. for having 1½ tons of midden refuse carted three miles, and it costs the Local Authority a good deal more than the sum they receive.

33082. Collecting and carting ?—No, the carting alone costs a good deal more than they receive from the farmers, so it practically is given away with a bonus.

33083. I see ?—And there is a very large agricultural area all round this town of 20,000 people. The 20,000 people are mainly a working class population.

33084. Do the farmers do it to oblige, or do they attach any value to it as a manure ?—I think they do attach some value to it, but it is the same with the sludge from the sewage disposal works ; it is very seldom that the farmers will give anything for it. They cart it away if it is given them.

33085. And yet, what is called farmyard manure is extremely valuable ; that is to say, the excrement of cows and horses mixed up with straw ?—Yes.

33086. Is it because they do not know how to prepare the other stuff, or they think its value is so small, or there is so little excrement in it ?—Probably because there is so much rubbish with it in the way of broken pots and pans and vegetable refuse that is not properly fermented and broken down, like cabbage stalks, and things of that kind, that take a long time to disintegrate.

33087. Is there not any way of keeping those things separate, the actual contents of the pails and the general house refuse, ashes and so on ?—It is extremely difficult to get that class of people to do it. As a matter of fact, they do not do it however much they are pressed. I believe leaflets are sent round and inspectors complain, but it has very little effect.

33088. Is any attempt made in the schools to teach that part of domestic economy ?—Extremely little. I should like to see it introduced, but, as a rule, the teachers think it is not quite their work and consider it *infra dig.* to deal with the subject. It is a great mistake, I think.

33089. Obviously ?—Because it is a necessary part of human life.

33090. Exactly. Then you say that properly equipped earth closets are practically unknown in this county, because the soil is so stiff and unsuitable ?—Mainly for that reason, I think. I have never seen an earth closet in Nottinghamshire. I have seen them in the south of England ; I have lived in a house where they were used, but then that was a country house where there were plenty of servants to keep everything tidy.

33091. Then, they use pail closets, do they not ?—Pail closets are used very extensively.

33092. And that means not covering the excrement with anything at all ?—Yes.

33093. When they accumulate it, they empty it ?—Yes. Pail closets are used in some of the schools, and it is always a trouble. In some of the schools, there is only a woman caretaker, and a woman caretaker will not and often cannot, carry away the pails ; they have to depend on the goodwill of a neighbouring farmer.

33094. Do you think there would be a considerable danger, in cases of disease, of those excreta spreading the disease by being removed, and during their transit affecting other people ? Would there be a greater danger than in the use of water closets in dealing with the diseased excrement on a large scale ?—As regards enteric fever, I think it is a much greater danger. I have known several outbreaks where I do not feel the slightest doubt that the pail closets were the cause of the spread of the disease. No other cause could be discovered, although it was very carefully searched for for a long period. Such outbreaks occur again and again. Very often a small outbreak that begins with infected milk or water continues for months and the continuance is kept up by local conditions. The only apparent explanation is the spread from the pail closets.

33095. Chiefly due to flies, I suppose ?—I think so. Of course, it is said that special precautions are taken in enteric cases, that special pails are used, and the contents of those pails are burned. But the cases become infectious very often for a week or ten days before the disease is diagnosed, and in that way the disease is spread. Very often it is not till the end of the first fortnight, sometimes the middle of the third week of illness, that the case is diagnosed as enteric fever, and up to that point no precautions are taken. And also the patient may remain infectious for a year or two years or longer after he is quite lost sight of.

33096. And all that time, I suppose, his excreta are infectious too ?—Yes, infectious at intervals ; the periods are not continuous.

33097. No, at intervals I remember; that is so. If earth closets were used, of course that danger would be lessened, would it not, because the excreta covered with earth would not be so liable to be attacked by the flies ? If the pails were systematically emptied and the contents buried, say daily, there would not be much danger ?—The answer to that would be yes, if it is properly done; but we have made great efforts in the schools to get the excreta covered with ashes—not so much with earth, because that is not available, but with ashes—and we have completely failed. The inspection and the supervision are not close enough.

33098. You say there are frequent complaints of the irregularity and inefficiency of the service. It is seldom that there is any cleansing or disinfection of the pails ?—Of course, that becomes a very expensive item. The "tips" that are used in the larger communities are apt to become extremely offensive. They give rise to dust and clouds of flies. No one knows how far they extend; whether they fly a few hundred yards or half a mile, or even more, if they fly down the wind.

33099. You say the difficulty of getting rubbish destroyed, of preventing accumulation, and of obtaining any semblance of cleanliness and tidiness is greater in country villages than in towns, and is prejudicial to the character of the inhabitants; but I should have thought it would be a question of education again ?—But we are having no education of that kind in the schools at present.

33100. No ?—The subject of hygiene is not touched in the schools at present. In a large country district (I have one in my mind twenty miles in diameter), one sanitary inspector can do little in the way of supervision.

33101. Very little, I suppose; has he any subordinates ?—As a rule he has none. Many of those are men who have had no sanitary education and have no sanitary qualification. To introduce anything into the country which requires close supervision until all sanitary inspectors possess some scientific qualification, and have had some special education would be courting disaster.

33102. You have been kind enough to give us a statement as regards the Conservancy methods for twenty-three districts which I think might possibly be taken as read and printed in our Report:

Inhabited houses - - - - -	69,573
Water closets - - - - -	21,640
Pail closets - - - - -	23,163
Privy middens - - - - -	23,876

—Yes; I do not think there is any reason why that should not be printed; the names of the individual districts are not given.

33103. (*Colonel Harding.*) There are one or two questions I should like to ask you. I think we are all agreed that where there is a good water supply, and where houses are gathered close together, water is the most practical way of conveying fœcal matter away from the houses themselves, but in country districts, where villages have scattered houses and, as a rule, have but a very scant water supply, the water closet becomes impossible ?—That is so.

33104. And quite undesirable if the water supply is not adequate ? A previous witness spoke to us about water closets being used with cans poured down occasionally to wash out the pan, but under these circumstances, you would not recommend water closets ?—No, certainly not.

33105. You spoke to us about certain villages in your district where there are even so few inhabitants as 250, where a public system of disposal had been found to be necessary, because some of the houses had not gardens attached to them; was that so ?—I do not think that was the only reason. I think if all the houses had had gardens, the complaints would still have arisen.

33106. But had you in mind any village where there were groups of houses actually without gardens in a rural district ?—Yes.

33107. But is not that a very exceptional condition ? In a rural district is it not almost invariable that a house has some sort of a garden attached ?—I do not think so in the older villages. Some of them in recent years may have obtained gardens at a distance.

33108. No gardens really connected with the houses ?—Where I live the population is 3,300; that is much less than the population of many so-called colliery villages, but many of the houses there have no garden.

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33109. Then, where houses have no gardens, evidently there must be some public system of collection ?—Yes, in the village I have in mind there is public scavenging.

33110. It is almost compulsory in those cases to provide a public system of collection ?—Yes.

33111. But, let us come rather to those cases of villages with scattered houses, and with what one might call, an inadequate water supply, where people probably obtain water from a pump in some central position in the village, and, owing to the labour of fetching the water in buckets into the houses, the consumption of water is relatively small ?—Very small, yes.

33112. Say possibly five gallons per head ?—Much less than that.

33113. Less than that, probably. Well, in cases of that kind, scattered houses where each house has, at all events, a small garden connected with it, what do you suggest to us is the right way of dealing with fœcal matter and with domestic water ? Surely the provision of drains, in circumstances of that kind, would be almost impossible, would it not ?—I think in many of those villages drains exist, but they simply discharge into ditches. The laying down of drains in the country villages now is progressing very rapidly.

33114. The provision of drains in the village does involve very soon some system of sewage disposal, does it not ?—Not soon; I think many of them go on for twenty years, or even longer, before there is any system of sewage disposal.

33115. With a convenient ditch and a convenient fall, there is a temptation to connect the house by means of a drain with it, is there not ?—Yes.

33116. Ought that to be encouraged, or discouraged in the villages ?—I should encourage the drainage and also encourage some adequate disposal. Very small schemes now can be made efficient.

33117. The moment you encourage the drains which saves the householders a good deal of personal trouble of a disagreeable character, you commit yourself before long to some system of sewage disposal, which, for a very small community, would be a costly business. Now, the alternative would seem to be—it is an alternative common enough in a very great many villages in this country and other countries—to dispose locally in their own garden of the fœcal matter, and the domestic water somewhere in the garden. The temptation no doubt is to pour it somewhere near the door, and it causes some smell there, and possibly runs down into the nearest ditch. But there are a great many cases where they really throw it out over the garden. Is not that really the best way of dealing with it ?—It is the only way available for them. Of course, in a great many of these cottages the man leaves the cottage at daylight, and in winter does not come back till after dark; it is left entirely to the woman or the children. If the woman is an invalid, or she is having children——

33118. Or, if it is pouring with rain ?—Or if it is pouring with rain.

33119. She does not go further than the door ?—Of course it is not done.

33120. But is it not, after all, the ideal thing to throw it over the garden ?—In a proper way, yes.

33121. In regard to the fœcal matter in such a case do you prefer a privy or a pail ?—In those very small communities, where there is no public scavenging, I think a privy midden, constructed according to the model Byelaws, is really better than a pail.

33122. Why ?—Because it does not cause so much nuisance from a moderate degree of neglect. Take neglect as the almost inevitable condition, and with a midden the consequences of neglect are not so disgusting as with a pail.

33123. But is there not this advantage of the pail over the privy, that the pail system requires more frequent removal ? The fact of the pail being full involves the necessity to empty it, whereas if you have the privy it will go on for twelve months and you may, therefore, get much larger accumulation ?—Not so long as that, if constructed, according to the model Bye-laws, of small capacity.

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33124. But if there is no public removal of contents, the probability is it never will be emptied until it is chocked full ?—I am afraid that is usual.

33125. Is not the pail system better, because the pail system does compel much more frequent attention ?—My experience, of course, comes chiefly from the reports of other people, but the reports of the nuisance caused by pails where there is no public scavenging, where they are not emptied by the public authority, are, I think, constantly increasing.

33126. The Commission is trying to get information as to what is the best thing to advise in the case of these villages with scattered houses which have inadequate water supply, and where a public system of scavenging is scarcely practicable, because of the poverty of the inhabitants, or the smallness of the community. Can you give us any idea, for instance, as to whether it would be best to recommend the pail system, or a privy system or a cesspool system ? Those seem to be the three alternatives. In French rural districts, the usual thing, as far as my recollection goes, is to have a cesspit immediately under the seat of the privy and domestic water is also poured into this place. There is pump connected with it, and this matter is looked upon in the light, which the Chairman suggested just now, as exceedingly valuable, and it is poured out over the garden as required for the vegetation, and when it is not required, it accumulates there. It smells no doubt. I am not quite sure whether the smell is really very dangerous, or whether it leads to the gathering of flies more in that semi-liquid state than it does in the ash-pit condition, which is usual in this country, but are you able, from any experience of your own, to suggest to us which of those three system you would advise ?—First of all, I should like to say that there is the assumption that the water supply is inadequate. I think the real remedy is to press that that inadequacy should be remedied. There are scarcely any villages in Nottinghamshire that cannot get an adequate water supply if they are willing to take it.

33127. But you would grant that the moment you get an adequate water supply, you must have sewage disposal ?—Yes, that is the point.

33128. And you are burdening this small community with a double cost ?—But they are suffering now from the want of water, and the injury to health from the inadequate water supply I think is the most important thing of all. Then, if they get their proper water supply, the sewage disposal becomes an inevitable consequence. whether they adopt the water carriage system of sewage disposal or not.

33129. And you think they should face that expense ?—I think it is inevitable, in the course of years ; I do not say how soon it can come.

33130. It is interesting to hear your view of this allied question of the water supply. Do you think it is the business of the County Authority to carry out some scheme of sufficient extent as to permit of the supply of scattered villages in its district ?—They have not the power to do it at present, but a very large number of the villages require no legislation to enable them to get water. They have the power of getting it from public supplies now wherever they choose to ask for it.

33131. When public supplies are available ?—They are available.

33132. But there are a great many cases where public supplies are not available, they are too far off. In that case, the village, of course, has the power to sink a well and provide a pump to do some absolutely local thing of that kind to provide itself with water, but do you think it is the duty of the County Council, or that the County Council ought to have the power to carry out a broad scheme to supply the whole district of villages with water ?—That is rather a difficult question. They have not the power at present, and so they have not the duty.

33133. Do you think it is desirable that they should have the power ?—I think, if they had the power to encourage, even if they had not the power to compel, a combination of a sufficient number of villages, they could then obtain water at a reasonable rate, whereas one village, acting by itself, cannot do so. If five or six or eight villages would combine, then they could get water as cheaply as some of the smaller towns.

33134. Then, in the absence of any adequate water supply, you think that really the action of Local Authorities should be to encourage the building of houses with gardens, so that the people may dispose of their sewage individually on their own premises ?—Yes, I think that should be so.

33135. That seems to be, more or less, an ideal arrangement, does it not ?—I do not think that cesspools or pail closets or middens are mutually exclusive. I think in all the houses, except the very small ones, both the cesspool and a dry method would be necessary unless the sewage runs into a ditch, because there are many of these smaller houses where they have a bath-room ; you cannot get rid of bath water.

33136. You cannot have a bath unless you have an abundant water supply. I am taking the case of hundreds of villages where the supply is simply by pumps. People do not indulge in baths under those circumstances, and, therefore, the volume of the domestic water is quite small, and in many cases a little sump at the end of the garden, which never overflows, which never requires emptying, is enough, the volume which goes into it from the few cottages is so small that absorption and evaporation take it up ?—For cottages, I do not suppose it is necessary. For houses, with six or eight or ten rooms, I think a cesspool is necessary, and in the very large majority of instances, certainly at Nottinghamshire, the cesspools are never emptied, because although they are made professedly water-tight when they are constructed, they never remain water-tight more than a few months ; in a year or two they all leak.

33137. I would like your opinion on that ? Is it desirable to attempt to make them water-tight ? Is it not better to build them with open brickwork, so that the ground could absorb what it can ? One is assuming, of course, that there is no well in the neighbourhood ?—If it is sufficiently distant from the well, I do not see any great harm in that. That is what does happen, whatever one wishes, and if during the first few months or year or two they remain water-tight, then they ought to have an overflow into some ditch.

33138. What is the evil of the ground being allowed to absorb the matters put into the cesspool—I am assuming the quantity is not large—the small volume that would be produced by a couple of cottages, for instance ?—None, except the possible pollution of water supplies.

33139. Apart from that, you see no evil ?—Apart from that I see no evil that I know.

33140. These matters absorbed into the surrounding soil would become dissolved, do you think ?—It depends on the character of the soil. In a gravel soil or sand, or even light loam, it would be absorbed rapidly. In a stiff clay, or in some of the Nottinghamshire districts where the magnesian lime-stone comes near the surface, it would either run away in fissures or not run away at all.

33141. Then, apart from the neighbourhood of wells, you see no objection to such absorption ?—Apart from the risk of contaminating the water supply.

33142. (*Chairman.*) You remember Dr. Poore pointed out in his book that if you had a clear space of about five feet round your well, any deleterious liquid by soaking through that five feet, becomes perfectly harmless.

33143. (*Colonel Harding.*) Becomes transformed.

33144. (*Chairman.*) Becomes transformed.

33145. (*Colonel Harding.*) Well, if you have a cesspool at a short distance from the garden and you have drains going into it, you are apt to have smells from it, which you do not get by the direct throwing out of domestic sewage on to the soil ?—That is so.

33146. You do not express any opinion to us, do you, as to whether it is better to throw the domestic water on the soil and bury the contents of the pail in the garden, and promote the building of cottages with little bits of land in connection ; whether that is not better than attempting a drainage system in these small villages. Are you able, from your experience, to tell us ?—I do not think it is, because it is so extremely difficult at present to get the class of people for whom that convenience would be

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provided to carry it out in a reasonable fashion. A man is usually at work almost the whole day and the woman will not do that kind of thing; she will not open trenches in the garden and put the rubbish into it, or the excreta into it, and if the liquid contents are simply thrown on to a bit of bare soil, in a very few days or weeks it becomes an intolerable nuisance.

33147. In that case I gather your view is, that in every village there ought to be some systematic arrangement for the removal of these matters, either by water, if an adequate water supply can be obtained, or by some contractor calling to take the matter away?—I think so. There are certain small villages in Nottinghamshire, where they have adopted public scavenging of that kind, very greatly to the benefit of the village; everyone is pleased with the beneficial results in several small villages of 200 to 300 inhabitants or less.

33148. It is quite possible, in these villages, to get a contractor to go to a group of villages and remove this matter?—Yes.

33149. The consequence is, it is tipped somewhere, and causes a great nuisance there?—It is usually in these cases taken to the farmer. I am speaking of villages of 100 or 200, or 300 inhabitants. The quantity there, which is removed every week, is quite easily given to some of the farmers and they take it.

33150. And it should be of considerable value?—That is an agricultural question. I do not think myself it is of much value, but I daresay I may be wrong.

33151. The Chairman alluded to the use the Chinese make of it?—Yes.

33152. There is no doubt they consider it of considerable value. And I have found, almost all over France, that this matter is looked upon really as very valuable?—Yes. It is so much mixed up with ashes in this country, that I think that very much damages its agricultural value.

33153. I daresay it does?—These people will not keep the ashes separate.

33154. Then, the only point is that these little communities that you speak of, for whom you recommend a public system of drainage, will have to incur very serious expense in proportion to the rateable value of their houses, and there is always the alternative that by teaching them to deal themselves, over their own gardens, with this matter, they save themselves a great deal of expense?—Well, I think the best reply to that would be that all these villages till recently have attempted to dispose of it themselves on their own gardens, or get their neighbours to take it, and it was because they felt the result was not as satisfactory as they desired, that they have adopted public scavenging. They have experienced the failure of the old system. I am not in a position to give you any figures as to the cost, but I do not think it has cast any serious burden upon those communities. I hear every year of several fresh villages that have adopted public scavenging.

33155. (*Mr. Willis.*) There is only one question I wanted to ask you. You mention here that you have received complaints as to the nuisance from refuse brought from adjacent towns to country districts. I suppose at present no one has much control over that? The town could buy land, say five miles outside or rent it, and simply take all its refuse there, and tip it. It does not need to get anybody's sanction to do that, does it?—Oh yes, unless they paid it out of current rate.

33156. I am assuming they do not want a loan. If they want a loan, I know they would have to get sanction, but supposing they merely rent the land, they have not to get the consent of the Sanitary Authority in whose district the land is?—No, certainly not.

33157. And I fancy the County Council have no power?—No.

33158. What I wanted to ask you was, whether you thought that satisfactory? I have heard myself numerous complaints around London, in Kent and Essex, of grave nuisance being caused by the carting of the stuff to these places. I gather you have some similar experience in Nottingham. I was wondering whether you thought some authority should have some power over that, if so, what is the nature of the power that they should have?—I think the districts into which these large quantities are brought should have some controlling voice. I do not feel any doubt that some of the outbreaks of enteric fever that I have seen have been caused in that way. At any rate, they have been investigated by many experts, and they could not suggest any other cause for it. The kind of thing I have in my mind is when hundreds of tons are sent out in that way, and they perhaps stand from Friday till Tuesday at a village railway siding, of course the Saturday afternoon and the Sunday intervening. During that time they become a very great nuisance. Then, they are carted along the roads to some farm and then, if there is any enteric poison in that material, the flies spread it to any of those who are susceptible.

33159. Now, what would you suggest?—Another place I have in my mind is where this goes by barges. I know a village where hundreds, if not thousands of tons, of this refuse are taken by barges and some of it tumbles off into the canal water. From the barges, it is put on to a wharf. There may be, perhaps 500 to 1,000 tons of it on this wharf. Some drops into the water in the process of wheeling and carting. Then, if there is a heavy rain, more is washed into the canal, and the canal is the drinking water supply of the village, and their only drinking water supply in summer.

33160. Yes, well what would you suggest should be done?—Well, they ought, at almost any reasonable expense, to get a proper water supply. The tendency in the towns I know best is to burn as much of this stuff as possible.

33161. Quite; that I know; but I suppose for a number of years, some towns will still go on adopting that plan?—Yes; I should hope it will diminish with the gradual burning of it more and more extensively.

33162. Do you think that any town, wanting its refuse to be carted into another sanitary district, should be required to get the consent of that Sanitary Authority for the arrangement, subject to an appeal to some body?—If there is an appeal to the Local Government Board. If the consent of the Sanitary Authority were required, I think every Sanitary Authority would refuse.

33163. Yes; would you say the County Council should consent then; they might be expected to take a more impartial view?—You are putting a very difficult burden upon them!

33164. But they are, in a sense, local people?—So long as there is an appeal to an absolutely impartial body, that has no local interest, such as the Local Government Board, I think that would be a sufficient safeguard.

33165. But do you think any further safeguard is necessary than you have got at present?—I do think so.

33166. I know that that view is widely held by other County Medical Officers of Health that there should be some further safeguard?—I get many complaints made to me, and all I can reply is, that I can do absolutely nothing.

33167. You have no power?—I have no power whatever.

33168. If the tip becomes a local nuisance, action can be taken under the Public Health Act?—But then you have to get some wealthy person to undertake the expense.

33169. Of course, the Local Authority could themselves take proceedings; I mean the Local Authority of the outside district?—Yes; but a small poor Local Authority taking an action of that kind in the Courts against a town of a quarter-of-a-million of people has no chance whatever of success.

33170. Well, it is an expensive proceeding; thank you very much; that is all I have to ask.

33171. (*Chairman.*) We are very much obliged to you indeed for your kindness in coming to see us to-day and giving us this useful information. I think what you have given us will be very useful indeed?—Thank you, Sir.

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APPENDIX TO DOCTOR HANDFORD'S EVIDENCE OF NOVEMBER 22ND, 1911.

In further support of the proposition that sewage disposal works have been economically erected and economically as well as efficiently maintained in the County of Nottinghamshire for even smaller populations than those given in my evidence, I am now in a position to give further details.

The following four hamlets are all in the Basford Rural Sanitary District, and Mr. Maylan, the Surveyor and Sanitary Inspector writes to me that "all have been uniformly satisfactory from the date of completion. The working expenses should not be excessive. Watnall averages one hour per day (labourer at 7d. hour)."

None of these districts were pressed to adopt sewage disposal works by the County Council. In each instance the need arose spontaneously from local complaint of nuisance. In none of the districts are water closets in general use.

The adoption of water closets would make little difference to the efficiency of the works.

I have seen each of them repeatedly and can testify that they are efficient.

The district is a mining one and the population are chiefly colliers.

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PARTICULARS OF FOUR SEWAGE DISPOSAL WORKS IN THE BASFORD RURAL SANITARY DISTRICT IN THE COUNTY OF NOTTINGHAMSHIRE.

Name of Outfall.	Estimated Population.	Description of works.	Approximate Cost.
			£
Beaufit Lane	220	Septic tank, revolving sprinklers, two series of bacteria beds.	250
Plainspot -	220	Septic tank, revolving sprinklers, two series of bacteria beds.	250
Jubilee Pye Hill.	200 (provision for 400)	Septic tank, revolving sprinklers, two series of bacteria beds.	500
Watnall -	200	Septic tank, two filters, sewage distributed over two bacteria beds through galvanised iron pipes fed by tippers.	150

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DR. GEORGE EDWARD SCHOLEFIELD, Medical Officer of Health to the West Lancashire Rural District Council, called in; and Examined.

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33172. (*Chairman.*) You are Medical Officer of Health for the West Lancashire Rural District Council ?—Yes, that is so.

33173. You have given us I think a synopsis of your evidence which I think should be printed in the Minutes. (*The following statement was handed in.*)

I have held the position of Medical Officer of Health to the West Lancashire Rural District Council since November, 1898.

The district at the time of my appointment consisted of seventeen townships, one of which, Formby, became Urban in 1905, and one, Ainsdale, in the same year, was taken over by the adjoining Urban District of Birkdale.

In the district as at present constituted, Aughton, Maghull, Scarisbrick and Tarleton have many residents who are engaged in business in the neighbouring large towns, and are semi-urban in many parts.

There is one colliery in Bickerstaffe, and the remainder of the district is agricultural.

The area of the fifteen townships is 60,436 acres, and the population at the last census 20,684.

The district near the coast is flat, not much above sea-level, but becomes more undulating a few miles inland.

Seven years experience of Formby and Ainsdale is included in this evidence.

The method of dealing with excrement varies. In Aughton there are public sewers, and water carriage is common; in Tarleton a small number of houses are connected with a short sewer; and other good houses have water carriage to cesspools. There are also earth closets, pail closets, privy ash-pits and occasionally a few old style privy middens are met with.

Scavenging at the public expense has been undertaken in Ainsdale, Aughton and Formby.

In Formby over 50,000 pail closets were emptied in seven years, increasing from 3,900 in the first to 11,700 in the last. In the same period 9,730 ash-pits, and 5,184 ash-bins were emptied, the average cost being for pail closets slightly over 2½d. per pail, for ash-pits 2s. 1d., and for ash-bins 3½d., the cost per removal being less in the last year than in the first.

Pail closets were gradually substituted for privies, leaving dry ash-pits and the residents were encouraged to use ash-bins instead of ash-pits. This increased the facility with which the refuse was removed from the vicinity of the houses, and also tended to produce greater cleanliness of the premises.

In Ainsdale privy ash-pits and ash-bins were emptied of the public expense for four years, and here the result was increased cleanliness, and less accumulations of refuse at the rear of houses. The cost averaged 2s. 2¾d. per ash-pit.

Scavenging was instituted in Aughton for a portion of the township in 1898, and for all, except the outlying houses, in 1903. The result has been most satisfactory. The cost to the rates has averaged 1s. 0½d. per ash-pit, but in some parts the house-holder has to pay the contractor 1s. to get the contents to the cart. As there are public sewers in this township no attempt is made to introduce pail closets, endeavours being made to convert privies into water closets.

In all cases the necessary supervision has been given by the Sanitary Inspector.

The drawbacks experienced have been: difficulty in every case to get persons to enter into a contract for the work required; also it has not been easy to find a depot sufficiently near the houses, and yet far enough away to avoid causing a nuisance. It is found that farmers will take the contents of pail closets, but not those of privy ash-pits or dry ash-pits.

In other parts of the district house-holders have to make arrangements with neighbouring farmers to take the refuse, or otherwise bury it in their own gardens. This of course is unsatisfactory, but it is difficult to see how it can be otherwise, as when houses are scattered the increased cost of public scavenging makes it prohibitive.

The opinion that I have formed on the question is, water closets are superior to any method of disposing of excrement, even if the connection must be with a cesspool. If public scavenging is adopted, pail closets with dry ash-pits are preferable to privy ash-pits.

Public scavenging is the most satisfactory method of removing excrement and other deleterious refuse from the vicinity of houses, but whether it can be adopted in a district or not is very largely dependent on the cost.

33173.* You have been for a considerable time in the West Lancashire Rural District ?—Yes, for about thirteen years.

33174. And the villages are becoming towns more or less rapidly ?—Well, not exactly towns, but they are becoming to a certain extent residential places.

33175. And they have been taken over by neighbouring towns ?—One village was, that is all; the village of Ainsdale was taken over in 1905 by Birkdale; that was a village of about 1,200 to 1,300 inhabitants.

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33176. The population is well-to-do, I suppose, in the district, is it ?—Yes, it is a fairly well-to-do population; it consists of residents who work in the neighbouring towns, Liverpool, for instance, Preston, Wigan, St. Helen's, Southport; and then farmers, mostly well-to-do farmers. The class of farming there is almost what we might style market gardening, farmers growing potatoes, cabbages and cauliflowers.

33177. To supply the large towns ?—To supply the large towns near, and then the farm labourers who work for them. Of course, the farm labourers are not so well off, although they are better off undoubtedly in our neighbourhood than they are in many parts of England.

33178. Then the formation of the land is flat; there is not much rise in it ?—No, the highest altitude does not reach 300 feet, and the greater part of the district is more or less flat.

33179. Have you got a special water supply, or are wells used ?—We have over 80 per cent. of the inhabited houses of the district supplied from public service, and the rest are supplied from wells, with the exception of a few where well water is bad, and they have rain water tanks.

33180. Then you speak of the methods of dealing with fœcal matter; public sewers in Aughton, and water carriage ?—Yes. Treated on land by downward filtration.

33181. A small number of houses are connected with a short sewer, and where does the short sewer deliver into ?—Into a tidal river, the River Douglas. This refers to the Township of Tarleton.

33182. Without any further purification ?—No, there is no purification at all.

33183. The volume of the river is considerable ?—Yes.

33184. So there is a large amount of dilution ?—Yes, a very large amount of dilution. Perhaps there may be twenty houses or so discharge into that short sewer, and the volume of water in each twelve hours is so considerable as to cause—well there is no sign of any pollution at all.

33185. Is it a tidal river ?—A tidal river, yes.

33186. Then you have also a certain number of cesspools, earth closets, pail closets, privy ashpits, and occasionally a few old style privy middens are met with ?—I think we have samples of every kind of sewage disposal that it is possible to think of.

33187. Then, no one of them apparently gets the preference ?—Well, the perference as far as the excrement is concerned, I think, is given to the privy ashpit, a plan of which I have forwarded.

33188. Yes, there is one attached to the Report you were kind enough to send us ?—I think more houses in the neighbourhood are supplied in that manner than by any other system.

33189. That keeps the ashes and the fœcal matter separate ?—No, it is not supposed to do that, but in actual practice we generally find that the ashes are not thrown into this ashpit, and you simply have the ashpit containing the excrement and a certain amount of water from urine, or water that may be thrown in. In that way it does not become a dry ashpit, as it ought to be in theory. The people throw their ashes very largely on the walks going up to their houses, and on the walks of their gardens' those who have gardens.

33190. I suppose they form the walk, as a matter of fact ?—They form the walk with the ashes, yes.

33191. Then what becomes of this fœcal matter in the privy ? Is it removed; is it emptied regularly ?—Those householders who have to deal with it themselves empty it when it seems to them necessary, or otherwise when the sanitary inspector finds out that it is absolutely necessary to remove it, and they either get the local farmers to take it, who as a rule will take it provided the trouble is not too much for them, or otherwise they bury it in their own gardens.

33192. I see. Is that generally done ? Do they live up to that, or is it an ideal state of affairs ?—Well, they live up to it fairly well.

33193. Those people are educated to do this; they feel it is a necessity. Is it a woman or a man who does it ?—Well, the man does the actual work, but it is generally the women that we have to talk to, because the man is away during the day doing his work at the time that any of us pay a visit.

33194. Then you do not require to visit all the houses; of course, that would be out of the question ?—Out of the question, of course.

33195. Does it get passed on from one to another in that way ?—Yes, it gets passed on, and if you get a little community of twenty or thirty houses, and one has to go there for any cause, and you find things not so satisfactory, then one gives them a little lecture which is very rapidly passed round, and also holds out a little more than moral suasion in the shape of what the Sanitary Authority will do if they do not behave themselves better, and we generally find that that little community is more cleanly, for the time being anyway.

33196. The contents of the ashpits or ashbins; I presume that also means the fœcal matter, does it not ?—Ashbins ?

33197. Yes, or no ?—No, not the contents of the ashbins. I think now you are referring to Formby.

33198. I am referring to Formby ?—Yes, in that township where pail closets were used, the inhabitants were encouraged to provide dry ashbins. They were encouraged to such an extent that the township provided these dry ashbins and sold them to the inhabitants at cost price, and in the ashbins there was nothing but ashes, and any vegetable refuse that they might put in. It facilitated the removal of this class of refuse very considerably to provide these ashbins, but of course in Formby there was a system of public scavenging—at least it was done by contract—and a considerable amount of money was expended each year on the removal of this class of material.

33199. Do the contents of these ashbins go to the destructor ?—No, there is no destructor in Formby. They were taken to a shallow pit outside the township, and there were covered up with a certain depth—about six to twelve inches—of soil, and everything that was at all of an obnoxious nature had to be covered up by the contractor who took it there. It was part of his contract that he had to throw soil or sand over it.

33200. Will this become land in future; is it a question of artificial land ?—Yes, at the time I ceased to be Medical Officer of Health to Formby, when it became an Urban District of its own, a considerable amount of land had already been reclaimed that was covered over with soil, and was already commencing to be used as grazing ground.

33201. But there is plenty of such land remaining ?—There was a fairly large pit at that time, a large shallow pit, that would take many thousands more tons before it was filled.

33202. You say that in Ainsdale privy ashpits and ashbins were emptied at the public expense for four years. Was there any difficulty in getting that done, in getting people to combine ?—There is difficulty in getting the parochial Committee to go to the expense of it; it was the cost.

33203. It is expensive ?—It is expensive. It was costing there in Ainsdale a little over 2s. for each removal. That put on to the township a rate of about 2d. to 3d. in the £. Eventually, in the last year that it remained within our district, it was about 3d. in the £.—the cost of it—for the removal of 562 ashpits; it cost £63 4s. 6d. altogether.

33204. Have they a good water supply there ?—Yes, practically the whole of the houses in that township were supplied with water.

33205. Then there would probably be baths I should fancy ?—Yes, there were baths and a fair number of water-closets too.

33206. What did they do with their bath water ? Did it go on the garden ?—It went to cesspools.

33207. To cesspools ?—And then the householders had to empty their cesspools on to their gardens, and they were always instructed and encouraged when that was done to dig trenches, and then to cover them up. In that way it was disposed of satisfactorily.

33208. And no difficulty was experienced ?—No, very little difficulty indeed in that township, where gardens were attached to the houses.

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33209. (*Colonel Harding.*) Did they agree that there was any advantage in the increased production of the garden by this system ?—Oh, yes, it is generally considered that, if you have fruit trees, you get a much larger crop of fruit.

33210. Did you find these people appreciate the presence of this matter for that purpose ?—Yes, many of them do.

33211. (*Chairman.*) Then you mention some difficulties ; the difficulty of getting a contractor ?—Yes, that is the chief difficulty. As an example of that, we are just commencing to have public scavenging in another community of about 1,500 inhabitants, and it has taken us nearly four years to secure a contractor to deal with the matter owing to the opposition of the people themselves to any increase of the rates. The local farmers and the local people were rather afraid to contract, owing to the odium it would bring on to them by the increase of the rates.

33212. But could it not be pointed out to them that if they were to have a water carriage system, the rates would be still more increased ?—Yes, and that is really the lever we have had to use to bring over the ratepayers, or rather to do away with the ratepayers' opposition ; we have had to threaten them that a sewage scheme would be necessary unless they adopted some system of scavenging to empty a certain number anyway of the cesspools.

33213. Do you find any nuisance arise from this ? In the streets for example, when the refuse is being taken away, is there a strong smell ?—Every contractor who removes material of this kind is compelled to have a vehicle that will not allow any of the refuse to be spilt about the streets as it goes through.

33214. Quite, and there is no difficulty in complying with that ?—No. In some cases, in the case that we are just going to commence, we are going to provide a special refuse-tight tank, so that it will be impossible for anything of that kind to happen unless great carelessness is exercised.

33215. Then the opinion you have formed on the question is that water-closets are superior to any method of disposing of excrement, even if the connection must be with a cesspool. If public scavenging is adopted, pail closets with dry ashpits are preferable to privy ashpits ?—Yes, that is so, Sir.

33216. And then you submit this plan of a privy ash-pit, which you are kind enough to furnish us with ?—That was one, Sir, that was drawn by the sanitary inspector some fifteen or sixteen years ago, and one of the advantages of it is that the floor is cement and the sides are cement, and consequently the bricks cannot become saturated with excrement, and also it is very easy to clear the contents out. There is a large door at the back, and also it does not contain a very large quantity. It has to be frequently cleansed.

33217. I suppose it is raked out with a hoe or something of that kind ?—Yes. The bottom, of course, is raised at least three inches above the surrounding ground, and the depth is about 15 or 16 inches—the depth from the bottom of the door.

33218. Then in clearing I presume the barrow is placed beside this movable door, the sliding door on the right of the second diagram, and by means of a hoe this is transferred to the barrow ?—Or a scoop, or something of that kind.

33219. (*Colonel Harding.*) Are the contents solid or liquid, or in what sort of condition are they ?—Well, that depends on the quantity of ashes that are put in. If there are no ashes, then the contents are semi-fluid owing to the mixture of foecal matter and urine, and possibly some times when the cesspool is full, the housewife may throw some slop water down there too. We are always instructing them, wherever we can get at the people, to put in some dry earth if possible, but there is always a considerable amount of difficulty in getting people to use dry earth, because, of course, unless it is dry then it is not of much use, and the people object to take the trouble to dry it in the houses.

33220. (*Chairman.*) And store it for drying purposes. I suppose the best plan is to make a heap of it under some sort of cover and leave it alone, and it will dry itself ?—It will dry itself, yes ; but somehow or other this class of country people seem to have an objection to doing that. It is too much trouble for the men when they get home at night or on Saturday afternoon, and it is very rarely that we find it done. That is why I am not a very great advocate of earth closets, on account of the difficulty of getting the dry earth to add to the excrement.

33221. Then you think that public scavenging is the most satisfactory method of removing excrement and other deleterious refuse from the vicinity of houses, but it is very largely dependent on the cost as to whether it would be admitted or not ?—Yes, because, while public scavenging may be exceedingly useful from the point of view of public health, at the same time if you are going to make it too expensive for the people who are living there, they will gradually go somewhere else, and of course your object is very largely defeated then.

33222. (*Mr. Willis.*) How do you empty this matter when it is in a semi-liquid condition ?—It has to be emptied then with a form of scoop that will take up the contents.

33223. Then you put it into a water-tight cart ?—Or very often you find the people, when they do it themselves, put it into large pails and distribute it about the garden.

33224. (*Colonel Harding.*) You spoke to us about certain small communities containing from twenty to fifty houses, and you said that you tried by a kind of missionary effort to train those people into better cleanlier methods. Now, in cases of isolated communities of that kind, you do not think it is very practicable, do you, to introduce public scavenging ?—No, the cost would be too great in those circumstances.

33225. Very well, what are you suggesting in the case of villages of that kind as the best way of meeting this difficulty, and avoiding the nuisance ? Do you suggest to us that it is better that the people should have the pail system, or that they should have a privy after the fashion of the one you have given us an excellent plan of ? Do you suggest it is best that they should have a cesspool ? If they have a cesspool, and if they have not a water supply, it is impossible to have a closet, it would be also too expensive, and the privy therefore would have to be over a cesspool. These are three suggestions which I should like your opinion upon, and possibly you may have a fourth or a fifth of your own to make to us ?—Under these circumstances I think the best means of disposing of refuse is by a privy ash-pit of this description, and a separate cesspool which should be 50 feet away from the house.

33226. What is the cesspool for if you have this ?—The cesspool is to take the slop water. If you could put the slop water in here it would very quickly be full, and would have to be emptied practically daily. Then you would find people in a community of that description would not empty it sufficiently frequent, and then you would get serious nuisance arising.

33227. I gather that what you recommend is for the foecal matter, a privy of this kind ?—A privy of this kind.

33228. And also a cesspool for the domestic water ?—Yes.

33229. And you think it is practicable in villages of that kind to get the people, if they are properly taught and talked to, to take this and put it upon their gardens in some inoffensive manner ?—Yes, it is frequently done in our district. We frequently come across houses where there is no nuisance existing on the premises at all, and the refuse is dealt with exactly on those lines.

33230. Then in your experience do you find it possible to convince householders in these little communities that it would pay them to attend to these matters regularly, because of the increased productiveness of their gardens, and because of greater comfort by the avoidance of nuisance ?—Well, I think you manage to get them to do it better by teaching them that it is very much to their own comfort and to their own health to keep the premises in a cleanly condition, than to allow things to go too far, and so become dirty and disagreeable.

33231. Then you find in practice that you can get these people to empty these privies and these cesspools in such a way as not to be a nuisance to themselves or others ?—Yes, very largely we find that to be the case.

33232. In these small communities, is that what you recommend ?—That is what I would recommend in a small community.

Mr. Geroge Edward Scholefield.

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33233. (*Mr. Willis.*) How often has a cottager to empty that type of privy ?—That depends entirely on the number of the household.

33234. Assuming a household of seven people ?—Seven people ! Well, possibly about once a week.

33235. (*Chairman.*) And during the time there is no particular nuisance or smell ? This is not actually part of the house ; it is outside ?—This not actually part of the house ; it is outside, of course.

33236. And it does not make any particular smell during the week. There is no putrefactive decomposition ?—Well, not a very great deal during that time, and if the householders can be persuaded, either to put some ashes along with it or some earth, then the smell is hardly noticeable at all.

33237. Thank you. We are very much obliged to you for giving us this evidence. It has been very useful.

Dr. J. R. Prior, Medical Officer of Health, West Berkshire Combined District, called in ; and Examined.

Dr. J. R. Prior.

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33238. (*Chairman.*) You are the Medical Officer of Health to Reading, are you not ?—Medical Officer of Health for the West Berkshire Combined District ; I live at Reading.

33239. (*Mr. Willis.*) I think you were Medical Officer of Health for the Biggleswade Rural District, before going to Berkshire ?—Yes. I can speak chiefly of Bedfordshire, because I have only recently gone down to Berkshire.

33240. (*Chairman.*) You have given us a short *précis* ?—Yes ; I am exceedingly sorry it is so short, but I had a very short time in which to get it ready. (*The following statement was handed in.*)

Pail closets can be used with advantage in the following cases :

In small communities such as villages providing

(*a*) The constitution of the village is entirely rural in character, that is to say where the houses are detached or if attached only a few houses together.

(*b*) Where there is plenty of ground adjoining each house.

(*c*) If however, there are groups of cottages or single houses without sufficient land there can be no objection to the pail closet system providing scavenging is done at least twice a week, daily if possible ; such scavenging must be done under the direct supervision of an officer of the district council.

(*d*) If the majority of houses are insufficiently provided with land or if the district approaches urban conditions the system is unsatisfactory.

(*e*) Fixed receptacles should never be permitted and a bye-law prohibiting this would be useful.

(*f*) Dry earth is essential.

Disadvantages.

The first great drawback of this system, especially in the poorer class houses, is the neglect to use earth and the infrequency of emptying and cleansing pails. If this system is to work well, effectually and without nuisance, the following procedure is essential in my opinion.

(1) If each house has sufficient land and no scavenging scheme is in force, systematic and frequent inspection is required by the Inspector of Nuisances of the District Council, otherwise the condition of things is likely to become a constant nuisance, and this state of affairs has been brought to my notice on several occasions.

(2) Probably it is better in all cases where the pail system has been adopted, to have a properly organised scavenging scheme under the District Council and not the Parish Council, my own experience only extends to this work being carried out by contract and not direct labour, and I should say that, generally speaking, direct labour would fail in country districts. If carried out by the local authority it must be under the immediate control and supervision of the Council's Surveyor or Inspector of Nuisances, frequently the same person in rural districts. Judging from my own experience this system only works well where there is a scavenging scheme in operation ; if left to the tenants themselves it frequently fails, owing to the constant neglect and improper use, and the Inspector of Nuisance's time may be frequently fully occupied in looking after this matter.

Patent apparatus for application of earth is not necessary or desirable, box and scoop are sufficient. A lean-to shed is useful for storage of earth during dry season, otherwise earth not available in wet weather. Where cleaning is carried out by occupier there is need for instruction in methods and shallow trenching.

The dry pail system can be used and carried out perfectly well, but it requires intelligent use, and unless this be shown or constant supervision is employed, it is likely to give rise to serious nuisance. Respecting privies and privy-middens, in my opinion they should never be allowed in connection with new buildings ; the constant nuisance, the pollution of soil and water makes these altogether undesirable and should be disallowed.

33241. I suppose you would agree with us all—we need not go over that point again—that in the case of large populations water carriage is the only thing possible ?—Unquestionably.

33242. We are talking of small communities only ?—Quite so.

33243. And villages with comparatively small populations and scattered houses. We will take your first case, where the houses are detached, or if attached, only a few houses together ; in a case of that sort, do you approve of putting in a water carriage system, burdening the community with a water carriage system ?—No, Sir, I do not.

33244. You think that would be out of the question ?—I do, Sir.

33245. Far too expensive ?—Far too expensive.

33246. In that case, you would propose the adoption of one of the three alternatives suggested by Colonel Harding, one is a cesspool, the second is a privy, and the third is a dry closet ; have you any preference ?—For smaller houses, the dry closet is unquestionably better.

33247. Less trouble to keep clean ?—Unquestionably.

33248. Have you found the people well disposed to it themselves ?—They have to be taught and constantly looked after to do so, but after they have been hammered away at for some little time by the Sanitary Inspector, we undoubtedly find a very great deal of improvement.

33249. Do you get at the men or at the women ?—We generally get at the women.

33250. The men are out ?—There is no doubt a very great improvement does take place if the Sanitary Inspector really takes sufficient trouble to see they are properly taught.

33251. And give them reasons why they should be cleanly ?—And give them reasons, and give them printed instructions ; we issue printed instructions to them.

33252. Then, do they deposit the contents in their gardens ?—We teach them to dig a trench.

33253. Do you know Dr. Poore's Book on "Rural Hygiene" ?—Yes. I think some of these ideas are taken from his book, but not directly.

33254. That is his suggestion. In a trench the refuse can be kept as long as they wish, as long as is necessary. Plants are not growing on the soil on the top ?—The trench would simply be opened for three or four inches, the accumulated material put in, and covered up.

33255. Dr. Poore's point is that the contents of that trench are dug up in two or three months and used as manure over and over again ?—Or utilised over and over again, and by digging a long trench he can commence at one end and start all over again.

33256. But he uses the contents of that trench as manure for the garden, as he requires them ?—We teach the people to do that.

33257. (*Mr. Willis.*) How often do you teach them to empty the pails—daily ?—We do, Sir. We endeavour to persuade them to do it.

Dr. J. R. Prior.

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33258. That is the ideal thing?—That is the ideal thing.

33259. (*Chairman.*) Is it the man or the woman who does it?—The man, as a rule.

33260. The man would dig the trench, but is it not the woman who empties the pail?—No, Sir, the man would, in my experience, do the whole thing. If there is no man in the house, they would get some one to do it for 1d. or 2d.

33261. Is there any trouble in cleaning the pail?—They scrape it out; they clean it out with a little earth as a rule.

33262. Then, you have solved the problem of getting people to do what you tell them?—Partially so, Sir.

33263. Is it spreading?—Undoubtedly it is improving. It requires a very great deal of real looking after by the Sanitary Inspector to start them.

33264. It is the Sanitary Inspector's business to do this, to show them?—It is generally delegated to the Sanitary Inspector to see they are properly kept clean.

33265. Do you find the lesson has to be given to each individual householder, or is it passed on from one to the other?—It is passed on from one to the other. We instruct the Sanitary Inspector to visit as many houses as possible.

33266. And then it would be passed on?—Exactly.

33267. Have you experience of public scavenging?—Yes, I have. A good deal of experience. I have initiated several public scavenging schemes. It is of great importance. If it is a rural community and some of the houses approach urban conditions at all, that is to say rows of houses and so on, I think a scavenging scheme is almost essential for its success, because it is rather too much for the Sanitary Inspector to look after constantly, and there is no doubt, that where a scavenging scheme has been introduced, it has brought about an enormous improvement.

33268. Is there difficulty in getting people to scavenge?—I have never known the difficulty.

33269. Is it expensive?—It is rather expensive. I have a figure here, a community of 900 people costing £1 15s. a week. The number of houses is 235.

33270. You do not know how much that would be in the £ on rates?—No.

33271. A few pence?—Oh, yes; it would be undoubtedly 3d. or 4d. on the rate, quite that and in some cases higher, but this depends largely on the number of houses in the district. I went into the figures, but I have not got them with me.

33272. (*Mr. Willis.*) That is a very small thing to each house. Most of the houses would be under £20 rateable value, and 1d. on the rates would be only 1s. 8d.?—Yes, very little. There was one scheme, with which the Local Government Board is dealing, owing to the Parish Council taking very strong objection to the increase of the rates. In that case it was 3d.

33273. In that case it is only about 3s. a year on the house. I suppose there is one disadvantage about that, that the rate is levied over the whole parish and that everyone would be rated even though he is a farmer?—Unquestionably, and that is why I think a scavenging scheme is so essential. I have known cases of small communities where the Parish Council have endeavoured to overlook it themselves, so as to keep it away from the Sanitary Authority directly. The consequence is that they have charged the people only who have to be looked after. It has generally produced a great deal of ill-feeling. After all, it is for the benefit of the community, as a whole.

33274. You prefer to spread the cost over the whole parish?—Undoubtedly.

33275. (*Chairman.*) Would not the view be taken that after all, what you are trying to prevent is danger to the public?—Exactly.

33276. You are saving danger to the whole public by public scavenging?—Yes.

33277. (*Mr. Willis.*) That is the justification for it?—That is the justification for it, yes.

33278. (*Chairman.*) You say fixed receptacles should never be permitted, and a Bye-law prohibiting this would be useful. I am not quite sure what you mean by fixed receptacles?—I mean a fixed receptacle for serving as an earth closet. There are fixed receptacles.

33279. Which cannot be removed?—Exactly.

33280. Which have to be dug out where they stand?—Yes. If you have a pail, the whole thing can be moved and a fresh one can be put in.

33281. I see you hold strong views as regards privies and privy middens. They should never be allowed in connection with new buildings, the constant nuisance, the pollution of soil and water making these altogether undesirable?—I do, Sir.

33282. (*Mr. Willis.*) On that, about the privy middens, we had evidence from another gentleman, perhaps you were here, who said that of the two things, if each is to be looked after by the cottagers themselves, he preferred a privy midden to a pail closet, because it was not capable of becoming such an absolute nuisance by neglect?—I should say exactly the opposite, Sir. I should say a pail closet, per force of circumstances, must be cleaned from time to time.

33283. If it is full, they may allow it to overflow?—Their attention is drawn to it, and my experience is that they will attend to it far quicker than they will attend to privies or privy middens, the matter from which is a most abominable nuisance.

33284. A privy is liable to be neglected for many months sometimes?—Oh, many years, Sir.

33285. Many years?—Yes. Take a huge privy, if it is not cleaned out for two or three years, it becomes a most abominable nuisance. I have known actual instances in which people have never emptied it. It simply becomes a septic tank after a time; it gets semi-solid, and soaks away into the soil.

33286. (*Chairman.*) Do the pails require renewal very often; do they wear out?—They do wear out, but they last several months.

33287. They last several months?—Yes.

33288. They are ordinary zinc pails?—Zinc pails. I generally tell the people they cost about 2s.

33289. (*Mr. Willis.*) Did the Local Authority provide the scavenging in Biggleswade Rural District?—Yes, in some instances.

33290. Do you find any difficulty in getting any suitable dry earth for these closets?—I never found any difficulty in getting the earth.

33291. In the neighbourhood of Biggleswade, you have got plenty of suitable dry earth?—Yes, top soil.

33292. In many parts of the country, I suppose that is rather scarce?—It might be; not in my experience in either Bedfordshire or Berkshire.

33293. (*Chairman*). Thank you; your evidence will be very useful.

MR. WILLIAM SEAMARK, and MR. WILLIAM GEORGE, called in; and Examined.

Mr. William Seamark and Mr. William George.

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33294. (*Chairman.*) You are Mr. Seamark?—I am Mr. Seamark, yes, Sir.

33295. You live at Walton, do you not?—Yes, Sir.

33296. You are a tenant of Dr. Harley?—Yes, Sir.

33297. Have you been long there?—Seventeen years.

33298. Have you always lived in the same cottage? Yes, Sir.

33299. We want to know about the way in which you get rid of your sewage; is it the dry-closet system? But first can you tell me the number of people who live at Walton, or the number of houses?—In the village, Sir?

33300. Yes?—No, Sir, I cannot.

33301. (*Colonel Harding.*) Can you say how many houses there are in the village?—There are ten of them belong to Dr. Harley.

33302. And how many houses are there in the village altogether; would there be twenty, thirty, forty, or what? (*Mr. George.*) There are seventeen cottages.

33303. (*Chairman.*) Are they close together ?—Oh no, they are a long way apart.

33304. A good many hundred yards apart ?—200 or 300, Sir.

33305. They are scattered ?—Yes, Sir. (*Mr. Seamark.*) Yes, they are scattered about, Sir.

33306. Tell me, how do you manage to get rid of your sewage ; have you an earth-closet ?—Well, Sir, we empty it and put it on the ground, on the garden.

33307. Is it a pail that you use ?—No.

33308. There is a seat with a hole in it ?—Yes.

33309. And below that, what is there ; a pail ?—No, Sir, no pail.

33310. There is simply a place ?—Simply a place.

33311. And do you spade it ?—No, Sir, we put it all along the garden ; we have got a cottage garden.

33312. How often do you do that ?—Every week, Sir.

33313. Once a week ?—Yes.

33314. Any special day ?—No, we never have any special day.

33315. Just when it happens ?—Yes ; when we get time to do it like ; once a week.

33316. Does it get pretty full before you empty it ?—No, Sir.

33317. Is it solid stuff or is there water with it ?—No water.

33318. Part solid ?—All solid.

33319. Pretty thick stuff ?—Yes, Sir.

33320. Easily spaded ?—Yes.

33321. Do you dig a trench in your garden and simply put it in ?—Yes, we dig a little trench and put it in and cover it up.

33322. Do you put in any earth along with it ?—Yes, we have some lime on it when we want it.

33323. I mean to say, do you put some earth into the closet, so that the stuff mixes with the earth ?—Yes.

33324. You do that ?—Yes.

33325. Do you take any trouble about drying the earth or do you use just ordinary earth ?—The drains are there to take away all the slops and that.

33326. You turn your slops into the same place ?—No, not into this.

33327. You put your slops into the garden ?—No, they run away, right away.

33328. You put them into the drain and they just run away ?—Yes.

33329. They get into a ditch, I suppose ?—Yes, Sir.

33330. After you have trenched your garden in that way and dug in the stuff, do you ever use that again ?—Well, Sir, we dig it there and put some lime on it and dig it in when it has got thoroughly dead.

33331. You dig it all over the garden ?—Yes.

33332. You take it out of the trench and spread it over the garden as you require it ?—Yes.

33333. Do you find you raise better crops with that than without it ?—Yes, some sort of crops ; carrots and vegetables.

33334. It is good for vegetables ?—It is not good for potatoes, but it is good for carrots and plants such as that.

33335. Have you quite leave to do all that, or are you troubled ; does the Inspector come in and see what you are doing ?—He comes once now and again.

33336. Does he interfere at all ?—No, Sir ; he never interferes at all.

33337. He is quite contented with what you are doing ?—Yes.

33338. Does it give you much trouble ?—No, Sir.

33339. How long does it take you a week ?—About two or three minutes.

33340. That is not much trouble ?—It does not take long, I am very sure about that.

33341. Are you a married man ?—Well, I have been, but I am not now ; I lost my missus.

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33342. I was going to ask you, do you think this is men's work or women's work ? Could a woman do it ; would she like to ?—Well, Sir, as far as I am concerned, I do not think a woman ought to. If we are obliged to take it, I do not think the women ought to go and empty it.

33343. You think it is a man's work ?—There are a good many women who do it, but I do not think it is any woman's place to do it. I think our closets are a good deal better than they are, because they are a distance from the road ; I think they are all 30 yards from the road. They are all a few yards from the houses.

33344. Is it far from the closet to the garden ?—No.

33345. Quite close ?—It is close, but still we have got some, I daresay a dozen yards from the closet. That is where I generally empty mine, and so do most of them.

33346. Have you any reason to complain of this ; do you think it makes a smell, or does it trouble you in any way ?—No, I have never had a day's illness in Walton since I have been there.

33347. Do you not notice that the flies come near it and give you trouble ?—No, Sir ; not at all ; there is no trouble at all, Sir.

33348. (*Colonel Harding.*) Mr. George, will you answer one or two questions ? You have heard the answers of your friend, Mr. Seamark. I suppose what he does at his house, you do at yours, do you, or is it something different ?—(*Mr. George.*) Well, our closet is the same as his.

33349. You do the same as he does ?—Yes.

33350. You have a privy without a pail and once a week you take the contents out and bury them in your garden ?—Yes.

33351. And whenever you have buried them you have covered them up with earth ?—Yes.

33352. And the slop water, you say, you pour away ?—The drain takes that away.

33353. How does that go, is there a drain-pipe which carries it away ?—Yes, it runs down the fields.

33354. How far is the ditch into which it flows ?—The ditch which runs down ?

33355. Yes. Is it close by the street ?—Twenty-five yards off the street.

33356. Then, is there a drain between your house and the ditch ?—There is a drain against my house at the back which runs right the way down and falls ; it does not stay there.

33357. Then, there is a smaller brook along which it flows to the ditch, is that so ?—It goes straight down to the ditch.

33358. There is no drain-pipe ?—From the cesspool into the ditch.

33359. It is the overflow from the cesspool that goes into the ditch ?—No, it goes into the ditch.

33360. What is the cesspool for ; does it not keep it there ?—Oh, no.

33361. By cesspool, do you mean a receptacle into which you pour the stuff ?—Yes.

33362. And it flows right away ?—It flows right away.

33363. And is this arrangement, which you have told us about at your house and at your friend's house, common to all the other houses there ?—Yes.

33364. And there are about twenty houses in that hamlet ?—Twenty houses.

33365. Do you see any reason at all to alter that arrangement ?—No.

33366. You think it satisfactory ?—Yes.

33367. And the trouble that it gives is so small that no one objects to do it ?—No.

33368. Do you find, in fact, that some of the cottagers neglect the emptying of this little privy, and that they let the stuff accumulate there till it becomes a nuisance to their neighbours ?—No, Sir.

33369. You do not find that ?—No, they are all kept clean and respectable, Sir.

33370. For their own sakes they empty it regularly ?—Yes.

33371. You see no necessity for carrying out any other system ?—No.

Mr. William Seamark and Mr. William George.

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33372. Has it been suggested in your little village that there should be any public collection of this stuff ?—No, Sir, not that I am aware of.

33373. (*Mr. Willis.*) Has anybody grumbled at the present arrangement ?—No ; nobody has ever said a word about it.

33374. The Inspector is satisfied with the closets ?—Yes.

33375. What is the name of your village ?—Walton.

33376. Down Streatley way ?—Yes.

33377. (*Sir William Power.*) Where do you get your drinking water from ; have you a well to each house, or a pump or what ?—From the waterworks, Sir.

33378. Is there water laid down to each cottage ; has each its own supply or do you get your water from stand pipes in the roadway ?—These pipes come underneath the ground.

33379. (*Mr. Willis.*) Have you a tap in your house ?—No, in the garden.

33380. (*Sir William Power.*) You can use as much water as you please ?—Oh yes, Sir. It runs very freely every morning.

33381. (*Chairman.*) We are very much obliged to you. We wanted to know how people, who use the closets, do about them. We are very much obliged to you for coming and telling us ?—(*Mr. Seamark.*) I think they are best as they are. (*Mr. George.*) If you were to leave it for a week or two you would have to pour a little lime on the top of it. With a family, you would have to empty your bucket every day, but if you do it once a week now, it does not matter.

33382. Well, it only takes a minute or two to do it ?—You have only to take a shovel and dig it out there and then.

33383. After you have shovelled it out, is the pit or whatever it goes into dirty ?—Oh, no, we swill it over with water with a little lime or anything like that.

33384. You put in lime ?—Yes.

33385. And that cleans it all up again ?—Yes, and you can freshen it up.

33386. Many thanks. Thank you very much.

PROFESSOR EDWARD VAUGHAN BERKELEY HARLEY, M.D. (Edin.), M.R.C.P., F.C.S., University College, University of London, called in ; and Examined.

Professor Edward Vaughan Berkeley Harley, M.D., M.R.C.P., F.C.S.

22 Nov., 1911.

33387. (*Chairman.*) For form's sake, I must ask you, are you Professor Vaughan Harley ?—I am.

33388. You are in practice in London ?—Yes.

33389. And you have a farm at Walton ?—Yes.

33390. On which there are a good many cottages ?—I own myself, fourteen of these.

33391. We wish to ask you about the method in which they dispose of their sewage ; we have already heard that from them. They appear to have outside closets, in which they do not use pails, but simply spend two or three minutes a week in cleaning their closets, cleaning them out with water, white-washing them and making them sanitary for the next week ; have you seen that ?—Ten of the cottages at the present moment are fitted up with what they call the old-fashioned pit, that is a concrete pit which they clean out in the way they speak about, and the other four, which have been altered according to arrangements with Mr. Thomas at different times, have got buckets. Now, I believe that is the present idea. He says that the pits are not very useful. He has not absolutely told me that I must replace these pits by buckets, but he has practically hinted it might be done. I went round to the villagers and spoke to them. They all of them strongly objected to have their pits turned into buckets. Those who have buckets do not like them at all ; they say instead of being useful to them, they add to their trouble. If they had a big family, they would want to empty them nearly every day. They have not the time to empty them. And they are also very much harder to empty than a pit, they say. I cannot see why they should be, but that is what they say. My objection is, first of all, if it is not doing any sanitary good, I do not see the good of spending the money on it. When Mr. Thomas had it altered, he had to take up the floor. There was already a tiled floor, and he put it at a different angle, slanting towards the door. The idea of that is, if the bucket got over filled, it would get in their footway and make them clean it out. That is the idea of sloping it all to the door. In the present set the floor has no slope—there is no connection with the concrete wall, so that it could not come out that way. The only way of emptying it out is at the outside where there is a hole, and that is covered in. Another thing Mr. Thomas made me do in two of the cottages was to put two glass windows in the wall.

33392. Of your own, or theirs ?—Of theirs ; what they use. The objection to glass windows in the wall is, first of all expense, and secondly I do not see they are any advantage. I think the great advantage of a privy is to keep it as dark as possible, to keep flies away. If you make it quite dark, there will be fewer flies than when you have plenty of light. The window is facing the kitchen. It is a distance about the width of this room from the privy across to the kitchen. They are facing that way. He could not put them on the other side, because they would be facing the sun. I consider he has done harm in this privy arrangement by putting windows in, and I do not see he has done any good by putting buckets in, and if he does the same in all other cottages, he will do the same damage.

33393. What right has he to put in windows, or to alter the system ?—I believe he has no right whatever. As far as I can now make out, by the Rural District Council Bye-laws, he seems to have no right. He ordered me to do it at once. He refused to see me—he never found it convenient to see me on a Saturday.

33394. Has he the right to order you ?—He writes on official paper and says he is the District Surveyor and this must be done. I took it for granted he had the right.

33395. Suppose you refused, what would happen ?—I do not know what would happen.

33396. (*Colonel Harding.*) Would they do it at your expense ?—What my bailiff told me was, that if I did not do it, they would do it and charge me a great deal more than I would pay if I did it myself. They would do it a great deal more expensively.

33397. (*Chairman.*) You object to do useless alterations, which are not only useless, but to some extent, insanitary ?—The bucket I will not say is insanitary, but it is not more sanitary. The other alterations for waste water I consider are insanitary.

33398. What is that suggestion ?—The only suggestion I got was that I was to put in certain things. I told my bailiff to see that whatever was wanted was done. Originally, each cottage had in front of its door a drain which ran into the ditch about 20 yards away.

33399. An open drain ?—No, it is a covered drain with a gully trap. All the cottages have gully traps. They must have gully traps and the drain flows absolutely direct into the ditch. When Mr. Thomas put his new arrangement in, he had to put 50 feet of a 6-foot drain into the cesspit. In the course of this drain he had to put an interceptor, then from the cesspit another outfall into the ditch.

33400. Is this a true cesspit, because your labourers told us that what they were employing was not really a store of any kind, but merely a place, a sort of tank into which they put their slop water, and it ran straight away into the ditch without being stored at all ?—They have got the old system.

33401. He replaced that by a definite cesspit in which the water accumulates and overflows ?—A definite cesspit 6 feet deep, and about 5 feet square.

33402. Of concrete ?—Of concrete ; a certain thickness of brick, and a certain thickness of concrete, according to their requirements.

33403. What was the effect of storing ?—That keeps it back so that it allows it to accumulate and ferment and it gets much more foul than if it went straight into the ditch where it is evaporated by the sun and in wet weather it is washed away by the rain.

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33404. Does that include potato parings and vegetables or tea-leaves ?—If they put potato parings or tea-leaves down, they would block the whole system up.

33405. Do they do that with their present system ?—In the course of ten years we have only once had the drains up for blocking. They were blocked by a mass of tea leaves. That was in the other cottages which had not been altered. That was a simple affair, pulling up these drains ; this is quite different.

33406. Mr. Thomas's contention is that this slop water ought to be stored before reaching the ditch ?—I do not know what his contention is ; he never told me.

33407. Judging by his insistence on your making a permanent cesspool ?—No, I think myself what happens is, he is applying to an isolated cottage what ought possibly to be done if it were going into a sewer. It does not make any difference, because he is ventilating this cesspit with a tale-valve, as well as the outfall, but the tale-valve is only there as an ornament, because the outfall is in the open air, and naturally the ventilation is in that way.

33408. Is it at the end of a pretty high pipe, or something of that sort ?—No, it is only a low thing standing about 1½ feet high, just a pipe from the cesspit into the hedge.

33409. He is applying Town Regulations to a country population ?—That is my idea. To my mind, the simpler the arrangements are, the better for the labourers. They are none too cleanly in their habits. They will throw down potato parings if they will go down. Under our present system we cannot tell that they are blocked up until there is some kind of a sign of a real mess.

33410. Before that, you very rarely had them blocked ?—No ; I have only had one set of drains blocked out of fourteen.

33411. You are a medical man ; you, of course, keep some eye on the health of these people ; are they fairly healthy ?—Well, in my village there has never been any illness at all, practically that I know of, since I have been there—in nine years, and the only cottage which has been ailing lately—scarlet fever started—was the one in which he had put all his sanitary arrangements in. I do not say that the scarlet fever started there because of the sanitary arrangements.

33412. No ; that would be perhaps going too far ?—They are perfectly healthy so far as I know.

33413. Then, you are contented with the state of things as they are, and you think it is reasonably cleanly—your present method for the disposal of sewage by your labourers, and it is not merely reasonably cleanly, but it is also a considerable saving of material, inasmuch as they manure the gardens with the sewage ?—I think the sewage is perfectly right. I think the question of getting rid of the slops is a very difficult question. I do not see how they are to do it any better than they are doing, except going into the ditch. In some cottages it cannot go into the ditch ; they are too far away from it, and it lies out in the field.

33414. Does your agent take any trouble to instruct these people as to what should be done, or do they tell each other ? Is it an old-established custom, is it handed down, or is there any attempted instruction as to what is the best thing to do ?—I do not know ; I never heard of any instruction.

33415. (*Colonel Harding.*) I should just like to ask you as to the condition of this ditch. Is there any water flowing in summer time ?—Well, each ditch is different. The cottages are well apart from each other ; there is a distance of about a mile and a half in which the cottages are situated.

33416. There are several different ditches ?—There are several different ditches.

33417. Is there a stream flowing to it ?—There is nothing in the nature of a stream.

33418. This slop water, which flows into these channels, is probably absorbed by the banks ?—It is probably absorbed by the bank, except in very wet weather, when it is washed along the ditch.

33419. In dry weather, did you ever see a flow there ?—No, not in the ditch itself.

33420. Tell me, has there been any nuisance from any of these cottages ?—I never smelt any smell from any of the cottagers' ditches, except the other day, on Sunday last, when I went to see the ditch which had been altered, which allows the outfall, because I wanted to see where the pipes did flow, because I had not properly looked at them, before I came here. If you put your nose low enough down, you could smell the stuff that came out of the cesspit, filthy black stuff. My bailiff explained that it was much worse than from any of the other cottages.

33421. Do you think it is because the Inspector found the condition of your ditch very bad that he desired to introduce this cesspit ?—No, I do not think he did that at all. As matter of fact I understand he is going through the different villages and making them all do that, one after the other and he began with the bigger villages.

33422. Have you any reason to know what his object is in doing this ?—No object, except to employ labour.

33423. Then, have you protested to the District Council, whose servant he is, in regard to this matter ?—No, I have not protested.

33424. Surely that council, if there were no beneficial result to follow from this work, would not support its Inspector in insisting upon it, would they ?—I believe the Council have the greatest respect for the advice of the Inspector.

33425. As matter of fact, you have not endeavoured to question the wisdom of his action ?—No, I have not ; I have simply carried out his instructions.

33426. With regard to your own opinion about these cesspools, you have told us, probably with truth, that the stuff which went away in a fresh condition was less likely to cause nuisance than that which had been held back and allowed to putrify before it passed to the ditch ?—Yes, I should certainly think so, the longer it stayed in the cesspit—it is practically full of moisture—there must be a certain amount of organic matter there and cultivating ground for bacteria.

33427. The probability is that the size of cesspool which you mention to us would leave the flow quite three or four days at least, would it not ?—Oh, I should think, at the first start off, when they first filled it up, it took nearly three weeks to fill up.

33428. Then, before there could be any overflow, there is a three week's storage of this matter, therefore there would be very considerable putrefaction arise ?—Yes, very.

33429. And you suggest to us that is a mistake ?—I suggest that that is a mistake.

33430. If this matter flowed directly into the ditch it would become absorbed in the ground, before putrefaction arose ; is that your contention ?—My contention is that there would be less danger from going direct into the ditch. I do not say there is not a smell, when it is going direct into the ditch.

33431. There is only this point which might be urged in favour of storage in the cesspit, that it might keep back most of the solids ; what do you think of that ?—I do not see what solids are going down through the grating. There is supposed to be a grating.

33432. If there is a grating, which prevents potato parings and cabbage leaves and such like, going down, then the matter which passed direct into the ditch before the cesspool was put in would not carry with it perhaps suspended matter ?—No, but all the old drains have gratings on top of them, gulley-traps.

33433. They have ?—Yes, so that nothing bigger than tea leaves can go down.

33434. So your suggestion is that the introduction of a storage cesspool, under such circumstances, is a distinct mistake ?—I think it is a mistake.

33435. (*Chairman.*) It induces anærobic fermentation, instead of ærobic ?—Certainly, I think that is the risk. If it runs direct into the ditch it is exposed to the sun and dried, and rapidly dried, whereas in wet weather, it is washed away. It is safer for people to have it. In some of the cottages where you want to make the ditch, there is no room, and if you put it along the road, you have to go uphill which is impossible.

33436. (*Colonel Harding.*) Does your experience lead you to say that in little communities like that you have been describing to us, the disposal of domestic sewage and fœcal matter is perfectly practicable upon their own land

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at such expenditure of trouble that they are quite willing to incur it ?—I think quite. Of course, there is no bath system; they get tap water; they use very little water.

33437. (*Chairman.*) Have you talked to your neighbours at all about this matter ?—I am very seldom there and I see very little of my neighbours. But the few neighbours who are there, the ones I know, do not own any landed property with cottages, they only have houses with no cottages, and they do not know anything about it.

33438. Is it largely farming land; are there not labourers' cottages on the farms, too ?—Well, the other ones are villages.

33439. Regular villages ?—There are. It is quite a different question, where you have got drain-pipes, sewage pipes.

33440. Some sewage installation ?—At Brickhill and other villages, with 200 or 300 cottages the buckets are emptied by carts coming round every day, or every other day, I believe, to clean out the buckets. Those are cleaned for their labourers.

33441. (*Colonel Harding.*) Those are larger villages ?—Villages of 100 to 200 cottages.

33442. (*Chairman.*) Do you know what they do with it; do they spread it on land ?—I do not know; I have no experience.

33443. Thank you very much; it is exceedingly good of you to come and give us some enlightenment with regard to your rural experience ?—Good-day.

ONE HUNDRED AND FOURTH DAY.

Thursday, 26th June, 1913.

PRESENT:

Sir William Ramsay, K.C.B., F.R.S. (*in the Chair*).
Colonel T. W. Harding, J.P., D.L.
Mr. R. A. Tatton, M.Inst.C.E.
Mr. F. J. Willis.
Mr. R. H. H. Keenlyside (*Secretary*).

ALSO PRESENT:

Dr. A. C. Houston.
Dr. G. McGowan.
Mr. C. C. Frye.
Mr. G. B. Kershaw.

Dr. J. Gordon Parker, F.I.C., called in; and Examined.

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33444. (*Chairman.*) You are Principal of the Leather-Sellers' Company's Technical College, London ?—That is right, Sir.

33445. You are also Examiner in Tanning, Leather Dressing and Dyeing of the City and Guilds of London Institute ?—Yes.

33446. You are ex-President of the International Association of Leather Trades Chemists ?—Yes.

33447. And you are Honorary Secretary and Consulting Chemist to the United Tanners Federations of Great Britain and Ireland ?—That is right, Sir.

33448. You have been kind enough to give us a synopsis, in answer to certain questions which were put to you, as regards, first of all, the different classes of tanning. I do not think we need put further questions as regards that, except so far as it treats of the substances used for tanning. I will leave that to others, and go on next to the processes which these various materials are subjected to, because, after all, we have to deal with the excreta of the tanner's yard, not the tanning itself ?—Naturally.

33449. You distinguish between fellmongers and tanners; would you kindly explain the difference ?—Yes. The fellmonger is the man who buys the sheep skins with the wool on direct from the butcher or direct from the market, and his sole duty is to take off the wool, and so prepare the pelt, that is, the skin, for the tanner's use. He does nothing more than take off the wool.

33450. Does that apply to ox-hides ?—No, only to sheep-skins; the fellmonger is only the man who handles sheep skins or sheep pelts.

33451. Then they go to the tanner ?—Then they go to the tanner.

33452. I suppose the question of goats is not a very important one ?—Oh, it is, Sir. The goat-skins, more or less, occupy a branch of their own; they are nearly all chrome tanned.

33453. Then they would go to the tanner straight ?—They would go to the tanner straight. They come over dried or salted in the hair, direct from the various countries, from India and South America, and various parts.

33454. Then that being done, the next thing is the tanner, I understand, treats the skins with lime ?—The fellmonger does that too, Sir William. The general process of fellmongering is, the wool must not be touched by the lime, so they take the skin and soak it in water first of all to soften it, if it has been dried, then they lay it flesh-side upwards, and plaster that over on the flesh side with a cream of lime. Two skins are placed together with a layer of cream of lime in between. They are left for about 24 hours, and the lime acts upon the pelt, dissolving the roots of the wool, so that it may be easily pulled out by hand. Then they take the skin or the pelt, wool side outwards, and they have a long pole, and they fold it over so that the wool is inside, and swish it about in water, generally an amount of water, because the object is to get as much of the lime off as possible, so that the wool will not come into contact with it at all, otherwise the wool is damaged, and they, therefore, swill a lot of lime salts down the sewers naturally. And then, in order further to preserve the pelt for transit, because the fellmonger's yard may be 200 miles away from the tannery, they then give these skins a soaking with lime for three or four days, or even perhaps longer in summer, in order thoroughly to preserve them. Then they are thrown up and allowed to drip, and in that condition will keep good for three or four days in transit.

33455. That liming, is a subsequent treatment, after the liming to remove the wool ?—If a fellmonger is simply sending them across the road to the tanner, that is omitted, and he allows the tanner to do that. I would point out that the fellmongering industry is one of the most ignorant and biassed; I cannot use strong enough language.

33456. They are small people as a rule ?—They are small people, and absolutely ignorant. The result is their lime-pits in which they prepare these skins are sometimes never cleaned out from year end to year end;

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they are teeming with bacteria and are absolutely putrid, and they do thousands of pounds' worth of damage to the pelts.

33457. That opens up the question—is putrefaction never used as a method of taking off the hair; actual putrefaction ?—It used to be, and it is used in some isolated places to-day. It is nearly done away with. The old principle used to be hang the skins up in a damp underground chamber, drive in a little steam to bring up the temperature, leave them hanging there for 48 hours, then you have an incipient putrefaction going on, with the ammonia naturally, and the wool loosened, but that was very dangerous to the pelt, as the grain was made so tender that the man, in pulling off the wool, used to pull off the skins as well, and the skins used to be pinholed. That showed on the finished leather, and rendered the skin second class.

33458. Have the fellmongers any idea, in leaving these lime-pits unfiltered and unchanged, of making use of putrefaction ?—No, I do not think so at all; it is merely a matter of pounds, shillings, and pence. I do not think they know what putrefaction means really, or the damage done.

33459. One comes across the words, "soaks," "bates," "pures"; can you explain them; what are they ?—"Soaks" are pits of water generally in which the hides or skins may be soaked to soften them. Hides come from all parts of the world, some of them sun-dried, and they are as hard as horn; they have to be soaked for as much as six or eight days. Then, the ordinary American hides, or hides from the Continent, come in heavily salted; that salt has to be got rid of. Then those that come from the butchers covered with blood, the blood has to be got rid of, so they are soaked for various purposes from two to eight days, in order to get rid of the various matters.

33460. In water in iron tanks ?—Never in iron tanks.

33461. What sort ?—Generally brick or wooden tanks; iron is fatal to tanning. Generally speaking, after the soaking, nearly all hides or skins of any kind go through a process of liming for a given period of time varying from six days up to eighteen, or even twenty-one or twenty-two days. The object of liming is to swell the pelt, swell the skin, and so loosen the hair, and also saponify the grease, open up the fibres, split the fibrils of the skin open, so that the tanning may easily penetrate. That lime has to be got rid of again before tanning. For certain classes of leather, notably all leathers for soft purposes; I mean by soft purposes, upholstering, automobile work, purses, pocket-books, harness leather or dressing leather of any kind that is going to be subsequently treated to make it more or less a soft leather. I am distinguishing now the hard sole leather from the soft or upper leather. It has been the custom for centuries to pure or bate these skins.

33462. Are the words synonymous ?—They are not quite synonymous. A pure is a fermenting infusion of dog excrement. The bate is an infusion of fermenting hen or pigeon excrement. They have not been quite done away with yet although there are artificial scientifically-made pures or bates on the market. Bacteriologists have isolated the necessary bacteria, and one can now buy pure cultures with the various feeding materials and they are being used very largely in Germany and Austria, to a less degree in France and Italy, and less still in this country.

33463. Those are cultures of a particular bacteria ?—Of particular bacteria.

33464. Of two kinds of bacteria ?—Mixtures of three and four. It was been found that in dog excrement there are three or four different kinds of bacteria in close relation, which are beneficial, and it is the culture of these three or four which is used.

33465. Does that soften the skin ?—It has a most peculiar action on the skin; it deflates it and makes it quite flaccid. There is a strong bacteriological action going on, and these pures work well, and it has been found in the investigation of these problems that the natural fermentations play a part, such as the pancreatic juices, the other fluids which are formed in the process of digestion, and these play a very important part also in semi-liquefying the pelt and de-liming. The object of this bating is to reduce the skin to a flaccid condition, so that the subsequent mechanical action with a stiff knife may press out the roots of the hair, the hair sacks, the sweat ducts and the semi-liquified grease. It prepares them for this mechanical process. If you simply dipped the skin into these pures, and did not do anything afterwards, you would do very little good, but afterwards they are placed on a beam and pressed with a blunt knife which is sometimes made of slate or stone. You can see the grease or lime salts and hair-rests and all the pigment of the hair all coming out on the beam.

33466. That is done on the side on which the hair originally was ?—That is so, Sir.

33467. Then the next stage, I fancy, is to put the skins in the tanning pits, supposing ordinary tanning is gone on with ?—Yes, the skins then, dependent on what they are, either go into the vegetable tanning materials or the chrome tanning, or the alum tanning, or the oil tanning.

33468. I think we know more or less about the old tanning; that is simply a solution of material, bark, and mirobolans and so on ?—That is so.

33469. They are there for different lengths of time according to the nature of the leather ?—According to the nature of the leather, the tanning given in the case of sheep skins being two to four days, and for the best sole leather six or eight months.

33470. Then, as regards chrome tanning, what is the difference, I mean in treatment ?—There is practically no difference in the preparatory treatment, the liming and soaking is practically the same with slight modifications to suit the difference in chrome tanning. Chrome tanning is an empty tannage which does not fill the leather, therefore less bating and preparation is done because hide substances must not be got out. They want to leave as much of the natural skin intact as possible. Then, the chrome tanning is purely, as you know, a chemical process of putting the skins first of all into a bath of bichromate of potash, with some acid, and then reducing with hyposulphite of soda and more acid. It is a process of impregnating the fibre with chromic acid, and then reducing to a basic chromic sulphate.

33471. In the pores of the skin ?—In the pores of the skin a basic chromic chloride, or sulphate is deposited, depending upon what acid one uses.

33472. Does that take out the whole of the chromium from the liquors ?—It should do. In a properly-managed tannery, under chemical control, the chemist will re-make up his liquors several times, but with the skins going in carrying extraneous matters into the chrome baths it does not pay to re-make your chrome liquor too often, therefore, from a chrome tannery there are always some chrome effluents to deal with.

33473. Always ?—Always; there will always be some. In a yard which is not under careful chemical control there will be larger quantities, but there ought to be a minimum; it ought to be very little.

33474. Have any attempts been made to regain this chrome, to recover it ?—Yes, in one or two works there have been trials, but it has not really paid.

33475. I suppose there are not large enough quantities ?—There are not large enough quantities, that is a point.

33476. Then you spoke of oil tanning ?—Oil tanning is the manufacture of chamois leather or buckskin such as those white shoes that are used for tennis, and such purposes. That leather, after the same preliminary treatment, is put into a machine we call stocks, the skins are rolled up in bales, and more or less saturated with cod liver oil, and they go into a large iron vessel and great heavy hammers come down and hit them and pummel them all the time. With this pummelling they naturally dry slightly, and as the moisture goes out the oil goes in, and then you get really an aldehyde tannage. They can be saturated more or less with cod liver oil, and after the full proportion has gone into the skin, and they are thoroughly permeated, they are then hung up in a warm stove which is kept to a temperature of about 140° Fahr. They undergo a very active oxidation. The man has to be constantly in the room to see they do not get too hot. When they get too hot, he takes them down, opens the doors, blows through a current of cold air, and that process is repeated till no further oxidation takes place. Then those skins are taken and pressed either by hydraulic pressure or some principle of squeezing. The oil which comes out is known as degras which is a sort of oxidised cod oil. Then that does not take it all out. They are then put into a weak solution of potassium carbonate,

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and soda ash sometimes, warm. That saponifies the uncombined grease. Then, that is recovered by washing in warm water and the washings treated with sulphuric acid, the grease floats to the top and is skimmed off.

33477. Can it be used again ?—Yes ; not for the same purpose ; it is used by the currier or leather dresser.

33478. It is no longer capable of oxidation ?—That is so, and it may be interesting to note there are factories that do this performance simply for the oil, not for the skins. It is an interesting fact that you can continue to make degrâs several times from the same skin. After having pressed the skins to get out the degrâs, you can then retreat the skins with more cod liver oil, re-stock, allow it to heat, and thus recover a fresh quantity of degrâs ; and when degrâs was in great demand as it used to be in America, there were factories in existence that treated these chamois skins several times until they fell away, just for the sake of the Sod oil and the degrá. Nowadays, the sulphonated oils have partly superseded degrâs.

33479. In combination ?—Yes, the oil oxidises ; aldehydes are formed and other products.

33480. The aldehydes do the tanning. It is not like linseed oil ?—No, it does not get insoluble, it simply gets thick ; it is like cream almost.

33481. Then practically none of that is left in the hide, but there is an action on the hide ?—Practically none of the grease is left in the hide ; it must be freed completely, otherwise your gloves would be greasy.

33482. You spoke of another process still ?—Alum tannage, that is for glove leather pure and simple, with skins with the grain left on.

33483. Is it similar to chrome tannings ?—Somewhat similar. The skins are taken, and treated with alum, flour, and egg-yolk, the alum gets precipitated on the fibres ; it is an insoluble salt of alumina, and the gluten of the flour undoubtedly acts as a sort of filling agent, and then the egg-yolk is a fat liquor, an emulsified liquor, which makes the leather beautiful and soft.

33484. It is just rubbed on ?—No, it is drummed in in a big drum, about 6 or 8 feet in diameter, and the skins are put in this drum, are drummed and drummed, and the lid is opened, and warm air is blown in, and gradually the paste goes in, and that makes the ordinary alumed leather, which is really, I may say, from a scientific standpoint, hardly leather ; you can wash it all out again. You cannot wash a pair of kid gloves, they are practically ruined if you do.

33485. Are they washed with this process, or simply dried ?—No, they are simply dried ; all that has not gone in is scraped off.

33486. And used again ?—And partly used again.

33487. So there is no refuse practically from that process ?—No, very little, very little indeed.

33488. Then in many cases the leather is dyed ?—Yes, in very many cases indeed you give them over to the light leather manufacturer. The dyes are very largely aniline dyes to-day. The wood dyes have been very nearly knocked out. Log-wood is still used, peach-wood, fustic and a few woods of that nature, but generally speaking hematine crystals have taken the place of log-wood.

33489. More or less as in the case of woollens or silk, the dye is absolutely extracted from the dye-vat ?—That is so. In some classes of leather one has to use a mordant, especially of course with the basic dyes ; always with certain tans that bleed out we must fix the tan.

33490. Is that a usual alum or tin mordant ?—Tartar emetic, sometimes alum salts are used, and sometimes chrome salts are used. Tin is not used because tin salts have a very detrimental effect on leather ; it seems to undergo some change, and re-act upon the leather. All the red russia leather that smells so nice, if you keep it very long, it goes to powder.

33491. In certain cases disinfectants are used, are they not ?—That is increasing because one is learning that, in soaking these hides for seven or eight days in water, one loses pelt substance, and many tanners are now using various kinds of disinfectants. Carbolic acid is used to a limited extent ; formic acid is now being used, because that has a swelling effect, opening the fibres so that they absorb the mixture quicker.

33492. Formaldehyde ?—No, not formaldehyde, formic acid. Formaldehyde you cannot use because it has a tanning effect. I am getting the best results at the College with some dry South American hides, which sometimes used to take ten days to soften, by using formic acid.

33493. Mercuric chloride is used ?—That has been suggested by Mr. Seymour Jones, as a means of preserving hides, and killing anthrax spores.

33494. It is rather expensive ?—Well, they use very little, the percentage is very very small, it was going to work out at threepence a hide if it was done on a commercial scale.

33495. Is arsenic used for the same purpose ?—Very little indeed ; arsenic has nearly gone out. It used to be used in the leather factory in the liming process ; they used to add it to the liquor.

33496. Not as a disinfectant ?—No. It was chiefly used by the glove manufacturers in Worcester and Yeovil, and the districts where they make glove leather. The addition of 10 lbs. of realgar to a lime pit forms sulpharsnates of lime. It is claimed to give that elasticity which is so valuable for glove leather, that even when you look at a new pair of gloves they do not look as if they would fit you, but after you have had them on twice they fit your hand.

33497. That is due to arsenic ?—The manufacturers claim it is. Unless you add arsenic you do not get that elasticity which a nice piece of leather should possess. In the continental glove factories they use it ; in England we are not so particular ; we do not make the same light class of leather ; we go in for heavy tans. When you come to ladies' light gloves they are made by the French or the Italians.

33498. And they use arsenic ?—They use arsenic.

33499. I think I may say we have got some sort of idea now of the complete process of manufacture, and also what is produced by that process of manufacture in the shape of liquors. That was the object of asking you to give us an account of it ?—Quite so.

33500. Let us begin with the old-fashioned tanning. There is, of course, a quantity of oak-bark, or whatever it may be, with the vegetable refuse that forms behind after the tanning is over, does it not ?—Yes. I may say that the composition of the liquor, which runs away down the drain from an ordinary vegetable tannery will contain about $1\frac{1}{2}$ per cent. of solids, that is to say, $1\frac{1}{2}$ per cent. of insoluble matters.

33501. Just one moment before you go further, in case of misunderstanding. The materials for tanning, that is to say the oak-bark, or whatever it is, are all put in together ; there is no extract made of the oak-bark first and the liquors, but the liquors go in along with the hides, do they not ?—No, sir, no ; right through the first process of tanning, the early stages, the hides are suspended in liquor. Once they are right struck through or tanned through, then, instead of being suspended in liquor, they are laid flat in liquor, but between each hide comes a layer of tanning material. The object of putting that in is to give firmness to the leather, and to feed the liquors up as they are absorbed. But in the first process of tanning they are in liquor only.

33502. And these liquors contain extracts, that is to say, the liquors are made by digesting the bark ?—By digesting the valonia and all the rest of the tanning materials, mimosa bark, extract of bark ; they are made into liquor, and the tanner to-day buys many of these ready-made extracts because it is cheaper for freight.

33503. Then this liquor that remains in the tan pits is not, of course, thoroughly exhausted by the leather ; a great deal of the tanning is taken out ?—Yes.

33504. And what is done generally with that liquor ?—It goes down the drain.

33505. If there is a drain to run down ?—Yes.

33506. And is it objected to ?—It is in many cases.

33507. Does it smell ?—Yes, a little sour.

33508. Is it putrifiable—not seriously ?—Not seriously, because it always contains a considerable amount of lactic, formic or acetic acid.

33509. Of course, a certain amount of the skin is in the liquor, or is that all kept behind ?—I do not think there will be any skin substance, because tanning is a preservative.

33510. The process of tanning makes things insoluble ?—That is so.

33511. So the liquors themselves do not contain skin substance ?—No, it is very seldom one finds more than one-ten-thousandth part dissolved substances in a tanner's liquor. If we find more than that, we tell him to accelerate his process and not keep his liquors so stale.

33512. Perhaps one ought to have gone a stage further, and dealt with the treatment of the skins by the fellmongers. Is anything done in that case to purify the liquors ; they must be very offensive ?—They are offensive. Fellmongers' liquors are notoriously offensive, and the only thing some of the country fellmongers do when they run them away is that they run them through a series of pits.

33513. For settling purposes ?—For settling purposes only, and the clear liquor, more or less clear, runs down the drain, but there are many fellmongers that have had great difficulties, and they have been closed up by the Urban District Council and others who objected to them.

33514. Have you, or has anyone else examined any processes for purifying or clarifying those liquors ?—Yes, oh yes. I have examined some, and I have seen them at work in various parts of the Continent. They have been put near Hamburg. The effluent is allowed to settle and then flows through large vats continuing broken coke and other porous matters and undergoes bacterial treatment coming away quite harmless and deodorised.

33515. Is the liquor diluted before it is done ?—No, it is not ; it has sometimes to be partly neutralised if too acid, or *vice versa*.

33516. Then the actual tannin really runs down the drains after treatment ?—Generally.

33517. You say generally ?—Well, it does ; there is very little objection made by any authorities to the tanning liquor. It is when the tanning liquor comes into contact with the lime liquor that they object, because, of course, that gives a precipitate, and forms a sludge in the drains.

33518. If they were compelled to settle their liquors, would that be a great purification ?—This is done ; that gets rid of the solids then, and this sludge of tannate of lime, or whatever it is, is then carted away on to the fields. The farmers use it on certain lands but generally speaking, the tanner has to pay the farmer to take it away. In some districts the farmer will pay for it.

33519. What is done with the actual spent tan ?—It is burned, sir.

33520. Dried and burned ?—Not dried ; but pressed ; it is generally put in one of Crossley's apparatus, and made into gas, and drives the engine. Formerly it used to be burned with the coal in the open boiler.

33521. That disposes of ordinary tanning. Chrome tanning ; you have told us about that, partly, that the chrome is very largely extracted ; it might be wholly extracted ; and that the liquors which are run away from the chrome tanning should contain practically no chromium ?—That is so.

33522. But that the chromium has not profitably been extracted from these liquors ?—No, that is to say, you mean, chemically.

33523. Chemically ?—No, it has never been done profitably, but if a tanner makes up a bath to put through, say, 50 dozen skins, he passes those skins through and at the end of the time his chemist tests that bath. That bath can be made up again to the proper strength. That may be repeated two or three times At the end of the third time, that bath has got so dirty with extraneous matters brought in by the skins, that it is then better to put it down the drain.

33524. Is that objected to ; I suppose there is not very much of it ?—No, there is not much of it. And then, in the chrome process there are also many washing baths have to be gone on with. After the skins have been chromed, they must not go forward with any acid in them, so the acid has to be neutralised with several changes of water in the drum. Then, afterwards with borax or some very weak alkali just to neutralise the skins ; you could not keep the fat liquor in if the skins were in an acid condition.

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33525. Is this washing water impure ?—No, the washing water will contain a little sulphuric acid and a little hyposulphite salt.

33526. Which have been used to reduce the chrome ?—Which have been used to reduce the chrome.

33527. Hyposulphite or thiosulphate is always used ?—Yes.

33528. Then, in the case of oil, you told us there is practically no waste product ?—No, only those recovery liquors.

33529. To saponify the oil ?—To saponify the oil they always contain a certain amount of greasy matter. They are a little objectionable, but I have never heard of any chamois dresser having any trouble to my knowledge.

33530. They go down the drain as a rule ?—They go down the drain as a rule ; there is no objection to that. They do like you to put them through some filtering method that will remove any oil. They do not like the oily effluents.

33531. You mention trouble which has arisen at Westbury and Kenilworth, and other places ; have these resulted in lawsuits ?—No, I do not believe it has ever got to lawsuits, in fact I am sure they have not. Although this one at Westbury may still give a good deal of trouble, they have not settled it yet. The head of that firm is a bachelor, who employs, I think, about 2,000 hands, and he threatened a few weeks ago, if there was much more trouble, he would close the works. He has been fighting them for six years, and he has put down settling tanks and settling pits. They leave him alone for a year or two and then go at him again. Very unfortunately with this firm it is a case like that at Westbury with chrome tans. He gets skins that come from China and all parts. Some of his liquors have gone down through streams to the cattle ; they drink them, and get anthrax, and that is what has stirred up all the trouble.

33532. Another question ; we are informed that the rivers, for instance at Yeovil, and elsewhere, are full of anthrax spores ; indeed anthrax bacilli ?—I have heard that ; I daresay it is correct.

33533. Dr. Houston has just been telling us that the amount of anthrax in these parts of the country is considerably greater than elsewhere ?—Yes.

33534. Are any steps taken to destroy the liquors from the first washings of those skins containing the anthrax ?—No, Sir. Nothing has been done to my knowledge yet.

33535. To disinfect them ?—I do not think it has been done ; no, I am afraid it has not ; it has not been done so far. Of course, the Home Office step in after the case of anthrax is finished with.

33536. Naturally ?—And then, of course, they want whitewashing, and pits clearing out and disinfecting, but it is too late ; probably the anthrax has gone by the time. Probably they are on a different bale of skins from somewhere else.

33537. It appears to be very constant ?—It occurs very often, and I wish some means could be got by which the skins could be treated.

33538. To destroy the anthrax before the skins were touched ?—Yes, we are getting further on. This Seymour-Jones process of treating them with a dilute solution of formic acid and mercuric chloride gives, in nine cases out of ten, positive results. It may escape in one case. It has been tried, I understand, on various parts of the Continent, and most reports that come in on this are more or less satisfactory ; though not perfect, yet they are better than nothing.

33539. It does no harm to the skin ?—It does no harm to the skin, if it is used in the strength that he lays down.

33540. I do not know whether you have seen a map like this, showing the distribution of tanneries throughout the country (*exhibiting map to Witness*) ?—No, I have not seen this one.

33541. It is instructive ; it shows there, they are very widely distributed ?—Yes.

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33542. So, if anthrax is being spread abroad, it is pretty uniformly distributed ?—Yes, but you have got to cut these red things up a bit; I mean many of these, I am afraid, must be little fellmongers' places.

33543. No doubt; is that so ?—(*Mr. Frye.*) I think not; it is taken from the latest Directory of Tanneries; it includes all small tanneries, of course. (*Dr. Gordon Parker.*) Some of these do not exist, I am pretty certain. I think I know the inside of every tannery in Great Britain, and I see spots where no tanneries exist. Still, a man calls himself a tanner in the Directory very often when he buys and sells a few hides. He used to be a tanner in the olden days, probably before the trade left him. I see some of these down here, round in Wales there are two there, that I know are closed up within the last four years, but they are still in the Directory and still do a bit of trade buying and selling, and these small ones, Mr. Chairman; they are really very very small, these that are spread about in little places.

33544. Little villages ?—Little villages. Warrington Liverpool, Bristol, London and Glasgow are the principal centres for sole leather tanning.

33545. Which is the most important ?—Oh, the Manchester and Liverpool District.

33546. That is the largest seat of tanning ?—That is the largest branch of tanning.

33547. That includes leathers for boots, and so on ?—That includes everything that is made out of the ox-cow or bull-hide. We differentiate sometimes between tanners and leather manufacturers. We call a man who tans sheep skins and goat skins and calf, a leather manufacturer; we call the other man a tanner, but it is not a very proper designation, because the other man tans as well. Then, there is another trade which you may possibly come on to; I forgot to put it in my *précis*, and that is the trade of the leather dresser.

33548. Of course, we are only interested in these trades from the point of view of the waste product ?—Yes, well the leather dresser has a lot. He buys foreign skins already tanned in India, Australia, or wherever they may come from. These are just roughly tanned. Now, perhaps you could put it this way, that a leather dresser gets an order from Maple or some one like that, for 50 dozen skins suitable for covering a certain class of chairs. Well, he will go to a leather factor in London, where he will see bales of all classes of skins, and he will pick out just those skins that will suit that order of a certain size and quality. He then takes them to his factory, and the first thing he does is to strip out, as far as possible with water and the use of a little soda or borax, all loose tannings; that is loose and uncombined, which may be done in India with Indian tanning materials which are reddish or brown in colour. Generally, the skins are very dirty. Those done in Australia with mimosa bark have a pinkish colour, which is very objectionable; those which have been done in South America are red. He strips that tanning out and re-tans it and makes it a good colour and improves the product. All the stuff he strips out goes down the drain.

33549. I thought once tanned always tanned; that the leather tanned wherever it may be, in Australia, with mimosa, would not take up any more tanning ?—It will.

33550. It is not thoroughly tanned ?—No; it is not thoroughly tanned, and by this treatment with dilute alkali you can remove all the tanning which is not actually chemically combined.

33551. It simply remains in suspension in the skin ?—In suspension, and we might say, attracted by physical capillary attraction, or surface attraction.

33552. Is that done in towns chiefly ?—Yes, that is done chiefly in London; it is a great trade in London.

33553. And are there actual works for doing it ?—Yes, nearly every light leather tanner in London is a leather dresser.

33554. At the same time ?—At the same time. Take the big firm of Bevingtons, who tan the skins, from the hair to the finish, themselves; they also buy large quantities of East India skins, Australian skins, and dress them. Of course, almost anyone can be a leather dresser. It does not require much capital, a little place with a drum, a supply of water, and a machine or two; he can get thirty days' credit from the factor, he gets his money in thirty days from Maple's, or other firm, and so he goes on. There are a great many little men doing leather dressing; they are not so careful as the big men.

33554a. In a place like London it would not very much matter, because their liquors in London go into the general sewage system ?—They do, especially as very many of these tanneries with leather dressing works have old rights.

33555. They discharge into the drains ?—They discharge into the drains, and they have old rights too. There were some old streams in Bermondsey, where the sewage used to run down to the Thames, but when the sewerage system came in they gave up those rights to discharge into those streams, on condition that the sewers took them. I do not know what authority there had been in those days—this is going back forty or fifty years—but certain open streams in Bermondsey were closed up and sewers put down, and I think they closed them on condition that those in charge of the sewers would take their effluent.

33556. What you have told us, for which we are very grateful, comes to this, that supposing all the liquors from an ordinary tannery are mixed you get a precipitate which can be settled, which can be filtered off, and the liquor from that is fermentable. It can be purified by passing over the usual materials, coke, clinker, and so on, for bacterial fermentation ?—That is so.

33557. Would it be a great hardship if tanners and fellmongers were compelled to do that ?—I do not think it would be a great hardship to a large tanner, that is, a man in a big way of business, but the little man I do not think would find the money to pay £50, or whatever it was, to do that. These men are small. Of course, if several combined, some system of that kind could be undoubtedly worked, but I think I might put it—I think I am saying this correctly—that the feeling throughout the trade is this, that the authorities do not know what they want. They come to the tanner and say: "Look here, you must do something." "What shall we do ?" "We do not know, you must find out." He goes and gets advice; he may come to me; I try to find out what they want, and try to do it. If you go to the extent of spending £500 or £600 or even £1,000, and then they go to the Urban District Council and say: "We have done something; come and look at it." They do not say much; they come and look at it; they say: "Certainly, that is an improvement." In another year's time they come and say: "Do something else." There is no finality to the thing.

33558. Is the problem brought before you nearly the same in all cases ?—In nearly all.

33559. It is a straightforward simple problem ?—They say: "We do not like your effluent; take out the solids." We take out the solids, and then they say: "There is too much albumenoid ammonia going down." An effort is made to deal with that objection, and then they will come and say: "You are letting acid down; you are letting alkalies down." We do not know really where we are. Take one case, in which Mr. Bertram Blount and I were engaged some four years ago, on the premises of Messrs. Hepburn & Co., of Dartford. For years they had been discharging their effluent; the Dartford Urban District Council or the Dartford Council were taking it, and three times they came forward, and each time they wanted the effluent purified. Messrs. Hepburn & Co., laid down huge settling tanks, and ran the stuff through pebbles and bricks and all kinds of things, and for some time it went on satisfactorily. Then the Dartford people came to them nearly three years ago, and said: "Oh, we are not going to take your effluent any more, unless you will pay us a sum of money." I have forgotten what the sum of money was, but it was disastrous. Well, they are on the Creek there at Dartford, and they spent £2,000 in putting up a large area; they dug it out close to the Creek for the effluent to go in, after passing through a series of filter beds and settling tanks, very finely made. They dilute this with condenser water from their engine, and also with water from the Creek, and so keep the percentage of albumenoid ammonia below the standard allowed. But, of course, the Thames authorities are very particular; they are analysing that material. Every month or so an Inspector comes and takes a sample. As long as they keep their albumenoid ammonia to a certain degree, it can go freely into the Thames. There is a case in point where the Dartford authorities ought to have taken that at a reasonable price, but the price they put on was such that it would have ruined the tanner. This is one of the important tanneries in England, there being some 2,000 or 3,000 ox-hides per week, and employing a lot of men.

33560. And this would have been a very serious interference with their profits ?—Undoubtedly, and the fact of the matter was that, during the time, it actually got to the Maidstone Assizes. We went down there, prepared to fight, but they compromised at the last moment.

33561. (*The Secretary.*) The Dartford people sent it into their sewer ?—Yes, they sent it into their sewer, and suddenly they said—no, they would not give us any reason at all ; we had a talk with their bacteriologist, and he said the difficulty is, settling these pits. They have a big sewage farm, and they said sometimes our stuff works nicely, and the next day it will not work nicely at all. That is incomprehensible to me. They have gelatine works there that discharge a good deal of albumenoid stuff and gelatine.

33562. (*Chairman.*) Was it due to antiseptics being used ?—They do not use any antiseptics.

33563. (*Mr. Tatton.*) Was there much solid matter ?—There was a good deal of solid matter, but then they have taken that out for three or four years past. Then they said, our clear effluents were not any good to them. We heard all sorts of things, but they never made any specific charge. The Engineer said it was damaging his iron pipes ; the Chemist (that is all information obtained since) said, "We cannot work it on the sewage farm." We could never get any specific charge. These are the facts of the case ; now can you alter them ? We could never get anything definite, either in writing or in consultations.

33564. (*Colonel Harding.*) So far as we are concerned these different branches of trade may be divided into two categories, those that are connected with the sewer, and those that are not ?—That is so. Now, in regard to those that are connected with the sewer, I suppose you consider that the condition which the Local Authorities make, that the suspended matter is first to be settled is quite reasonable ?—I consider that quite reasonable.

33565. And do you consider it quite practicable ?—It is practicable where there is any land available, but many of the old tanneries are so built-in in towns that they could not do it. There are some tanneries, notably some in London, where I do not see they could put a settling-tank, because it takes up a good deal of room. You see, a tanner will have some 10,000 gallons of effluent daily. If you are to settle, you must let it go very slowly, through your various settling tanks to settle, therefore, unless one has room inside your own area, you cannot do it, as in Bermondsey one cannot get area outside, because you probably have houses next door.

33566. In the case of a Local Authority allowing that, it is not practicable for a manufacturer to put down settling tanks, and ask him to pay a contribution towards the cost of dealing with his waste material ; do you not consider that to be also reasonable ?—I do ; I think the tanner would also.

33567. Has that been done to any extent ?—I have never heard of any case where a tanner has been asked to pay for running his material down the sewer yet. They either say, "We can take it," or "We will not take it." I have never heard of any case where they have been asked to pay a contribution.

33568. But, obviously it is of great advantage to a person engaged in one of these trades, where foul effluents must necessarily be discharged, to be able to connect with the sewer ?—Yes.

33569. And you think that the condition is quite reasonable, that the manufacturer should be asked generally to exclude suspended matter ?—Yes.

33570. To what extent would you consider that, if he were asked to exclude suspended matter down to the point, that there should not be more than three parts per 100,000 ; do you think that would be quite reasonable and practicable of attainment ?—Three parts per 100,000 is rather low.

33571. (*Chairman.*) It precipitates fairly easily ?—Fairly easily, some do ; the lime one does, of course. But some of these other ones, for instance, a leather dresser uses more or less colloidal substances which do not settle very easily. One could put them through a special filter bed. I could answer the question in this way ; I do not think the tanner would object to anything in reason, if he knew exactly what was required.

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33572. (*Colonel Harding.*) I put it to you, that if he were required to reduce the suspended matter to that point, do you think it would be practicable for him to do it ?—Certainly ; given space, he could do it ; a man in the country could do it, undoubtedly easily.

33573. In those cases where there is no space, do you consider that it would be fair for a Local Authority to say : "We are taking into our sewer a quantity of suspended matter which we will have ourselves to settle and deal with, and we ask the manufacturer to contribute so much a gallon, say, towards the treatment ?" Do you think that would be quite reasonable ?—I do ; I consider that perfectly fair, perfectly fair, provided you take into consideration that the tanner is already a ratepayer, and you do not over-rate him, that is to say, if he is already paying so much in the £. for his ordinary rates, which is supposed to cover a certain part of the duties of the borough towards him, he must not be too much loaded up with this extra cost. As long as it is a reasonable matter.

33574. You agree with the principle of the charge, but you do not pledge yourself to approve any kind of a charge, of course ?—I always object to a charge if I can get out of it, and naturally they will.

33575. The worst cases arise where a manufacturer has not access to the sewers ?—That is so.

33576. In some cases, you have told us, manufacturers put down settling tanks, and they put down bacteria tanks ?—Yes.

33577. You mentioned one particular case, at Nottingham ?—Yes.

33578. You said he had been asked to do something else ?—No, I said he put down a filtering bed to put out his grease ; I did not say he had been asked to do anything else ; it was the case of Westbury.

33579. He had put down settling tanks, and he had also put down bacteria beds ?—No, he had not put down bacteria beds ; he had put down settling tanks and catching beds, and he now has been told he must do something to prevent any chance of any anthrax getting into these streams.

33580. Has anything been suggested to him by which he can accomplish that result ?—No, sir.

33581. Has sterilization been suggested ?—I really do not know what has been suggested to him, but he says he has got to the end of his tether practically, and if any more restrictions are put on him, he must close the works.

33582. Can you give me any instances where a tanner or fellmonger, or anyone engaged in any other branch of these trades, is not only settling, but to a considerable extent purifying the liquid portion of his waste ?—Yes ; oh, yes ; several. At Dartford, for instance, they are settling, and they are passing their effluent through a special apparatus designed by someone in Westminster here, in which it is treated with ferric alumina.

33583. That is simply as a precipitant ?—Yes, as a precipitant, and it clarifies the liquor too, and then it passes from there on to these special filtering beds. It is an upward filtration. Then that stuff is quite clear ; it is a double process. It first of all goes through ordinary settling tanks, then through this alumina feric, and then it passes through another filter after that.

33584. It is practically clear ?—It is practically clear ; it is almost like drinking water, to look at the effluent.

33585. What is the extent of the soluble matter ?—I could not say from memory ; it is very low.

33586. (*Mr. Tatton.*) It is a mechanical filter, where the sand is blown up afterwards ?—It forms upward, and then flows over bevelled iron plates, and all the solids keep at the side, and it flows into this little trough, and runs out into the side of the bed. It is an apparatus which has been designed by a firm in Westminster, and it is acting extremely well.

33587. (*Colonel Harding.*) Is this a tannery ?—It is a tannery ; besides being a tannery it is also a glue and gelatine factory. That also complicates it a good bit. A gelatine factory is much worse than a tannery.

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33588. Is the effluent from a gelatine factory the same as comes from an ordinary tannery ?—Yes, very much the same.

33589. And you suggest to us it is possible in that case to bring about a result that is good ?—Yes, quite good.

33590. Do you see any objection to it being laid down that that result should be obtained everywhere ?—No, provided there is space again, because this is taking up a very large space—these settling tanks. I suppose the plant is probably 150 yards long, by 50 wide.

33591. And it is financially practicable to accomplish that result ?—Yes.

33592. Then, does the difficulty of obtaining the same result everywhere arise from the fact that there is not space in the works to carry out this purification ; is that the only objection ?—Well, that is one of the objections, but the other objection is this, that when they are told to put down settling tanks, or advised to do so by the authorities after they put them down then the authorities are not satisfied, and they want them to do more, and they never know where they are to end ; that is their argument.

33593. Do you suggest it would be better for an authority to lay down a standard, a somewhat high standard, to make quite clear to these people what it is that they are expected to do ?—I think it would relieve the misunderstanding that exists at present.

33594. Suppose a standard were suggested to them, which they considered to be financially impracticable, would it not probably lead to nothing at all being done ?—Well, I suppose it would if it were impossible, but surely no one would suggest a standard which was impossible. They would first of all find out what was a commercial proposition, and then lay down that standard. It would not be difficult to find out what was commercially practicable.

33595. You say that manufacturers generally would prefer to be told the degrees of purification that they are to aim at reaching ?—Yes.

33596. And then be let alone if they do reach it ?—And then be let alone if they do reach it.

33597. May I ask your view as to this ; suppose that it is not possible at first to get a very high standard of purification, an arrangement were made by an authority with a tannery or with a manufacturer to do certain work, and then he was not to be called upon to do more for a fixed period—let me suggest five or ten years—would that be a satisfactory solution ?—That would be much more satisfactory than the present conditions.

33598. But do you think it is possible to obtain a high degree of purification by financially practicable means at the present time in fellmongering ? I gather you think there is in tanning, if there is space ?—Yes ; and in fellmongering too you could get an effluent free from solid matter, but you would always have, of course, the nitrogenous matter in solution, the albuminoid ammonia, and it would be an objectionable effluent from a fellmongering yard, generally speaking, because it is highly putrefactive, and would smell.

33599. Then, even if it were fairly clear and free from suspended matter, you agree it would be very objectionable still ; highly putrefactive ?—Objectionable to go down an open stream or river, but not objectionable to go down a sewer.

33600. Not at all, but at present I have finished with those that go into the sewer ; the real difficulty is with those that go into the stream ?—Yes, in country districts.

33601. What do you suggest should be done to purify that liquid, which is fairly free from suspended matter ?—I think it might be treated so as to render it non-objectionable.

33602. In what way ?—Bacterial treatment over coke.

33603. Are you expressing that opinion after having seen some experiments ?—Yes ; abroad.

33604. Where ?—In the neighbourhood of Hamburg.

33605. We shall be interested rather, if you would tell us first, whether it is a general rule that tanners and fellmongers are compelled to treat their waste liquors, and next give us information as to how they treat them ?—It is the custom in certain districts of Germany. I do not know whether it is the universal custom throughout Germany, but in Hamburg it is. Hamburg is a great tanning centre, but naturally, as land has become dear, people have gone out and built tanyards further out in the country where there is cheaper labour and cheaper rates. Strange to say, one of the tanneries there belongs to an English firm. They had to lay down this plant. They were constantly having trouble with the Local Authorities, especially the Medical Authorities, who said there were very objectionable smells emanating in the village from their effluent. They therefore asked the authorities to co-operate with them as to which was the best method to treat them. When they got the German authorities to agree, this question of the bacterial method of treatment was adopted and it really is simply passing the settled liquor over a series of coke beds dropping gradually down, and allowing then bacterial action to go on in these beds.

33606. Are these beds what are known as contact beds or percolating beds ?—Contact beds.

33607. Contact beds ?—Yes, there are about five of these contact beds each one about a foot lower, 7 or 8 feet deep. They gradually drop down till the liquor runs away to the stream.

33608. (*Mr. Tatton.*) Are they used intermittently, these contact beds ?—Yes ; they may be separated out and one cleaned or anything of that kind. They have seven ; they usually work five ; so that any two can be thrown out and put through the others while they are being treated.

33609. (*Colonel Harding.*) The liquor does not flow through them ?—They are very slow.

33610. It is a continuous action ?—Yes.

33611. It is not filling them and allowing them to stand ?—No, it is a continuous action. The liquor is regulated in by a tap flowing night and day, but always very slowly.

33612. Are these filters always full of liquor ?—They are always full.

33613. What kind of æration do they get ; are there periods of æration ?

33614. (*Mr. Tatton.*) Is the liquor syphoned from one bed to the top of the next, because you spoke of a foot of difference in level in them, and that they are 7 feet deep ?—It really is sloping down ; there is no object in that ; it is because they are sloping down to the stream.

33615. They must be kept continuously full ?—They must be kept continuously full. As to the æration, I do not know ; I think they had some means of ærating them, but I am not quite certain.

33616. (*Colonel Harding.*) Tell me ; the original clarification or sedimentation, is it assisted by chemicals of any kind ?—Generally chemicals are added to precipitate, that is to say, if a tanner is settling his liquor, he has got his lime liquors running in from one part of his yard, and his other liquors from the other. He so regulates those that he does not get an excess of lime, or an excess of tanning.

33617. Can you give us the address of a place where we could see, on a large scale, a process of this kind being carried out ?—Which do you mean ; the bacterial ?

33618. The complete treatment which you said gives such a result, that was so satisfactory, that you were tempted yourself to drink a glass of it ?—Exactly, you can see that at Hepburn & Co., Priory Works, Dartford.

33619. At Hamburg ?—Hallenstein & Co., Krempe.

33620. Is that done on a large scale ?—It is done on a very large scale.

33621. What is the nature of the tanning there ?—Sole leather tanning. I am perfectly sure Mr Hallenstein would be only too pleased to show you over.

33622. Are the Local Authorities there insisting on this kind of treatment being adopted by all tanners ?—That is the only one where it is in use ; I do not know anywhere else in Germany where they are doing it.

33623. Did I not gather from you that there are many tanners in Hamburg ?—Yes, but only one in this country district ; the others are nearer and they do not seem to have trouble.

33624. The others are nearer the estuary ?—Yes, and they do not seem to have trouble.

33625. (*Chairman.*) At Dartford, is the work carried out completely now ?—At Dartford it is going on very nicely now ; they are settling with a tank.

33626. But no bacterial filters ?—No.

33627. (*Colonel Harding.*) What can you suggest for the fellmongers who are not in a large way of business, and who turn out an exceedingly foul effluent ? You must see that, in the public interest, it is undesirable to allow these foul effluents to be turned into streams, especially into small streams ?—Yes.

33628. Can you suggest to us some way of bringing that about ?—Only by impressing on the fellmonger that he must not allow his effluents to get so foul.

33629. That is rather an interesting point. Are these effluents needlessly foul ?—They are in many cases needlessly foul.

33630. Would you explain that more fully to us ?—I thought I made that clear when I said at first they were very ignorant.

33631. In some cases in tanneries where chromium was used you said it ought not to be allowed to go to waste, but speaking of an ordinary fellmonger in a small way of business, in what way are his waste waters needlessly foul ?—I said that the fellmonger was very very ignorant, and was not aware of the bacterial changes that took place when he kept his skins in lime too long or used his limes over and over again, and education which could be picked up very well by these men would help the tanning trade very much, if you could impress upon the fellmonger that he is doing harm to the skins by letting his liquors get so foul ; he would then not discharge them so foul.

33632. Is not the best way of impressing the fellmonger for the Local Authority to say : "We will not allow this to be done," and then he will have to get wisdom in some way to avoid sending foul liquors ?—Yes, I agree with you that is one way and a very good way, and you would help the trade if you did that. There is no doubt there are thousands of pounds lost by the ignorance of the fellmongers. All attention is given to the wool and too little to what he calls the bye-product, namely the skin. As to wool values, you pay to-day 12s., 13s., or even up to 15s. for a sheepskin from the butcher with the wool on it. If you pay 13s. for the skin, you will get probably 12s. worth of wool out of it ; he will then sell the skin—the skin is the pelt, as we call it—for making the leather for perhaps 2s., and the other 1s. will pay for his labour and any profit. In the olden days there used to be a sort of golden rule for the fellmonger, if you pay 10s. for the skin, and you can sell the wool for 10s., you keep the pelt to pay for your costs.

33633. I am glad to hear you say that these waste waters are needlessly foul, and that it would probably have an excellent effect, if some pressure were put on by Local Authorities to reduce the foul effluent ?—Yes.

33634. But I suppose when they have taken every care, the waste waters would still be foul, would they not ?—They should not be what you would term foul ; they would not smell as they emanate from the fellmonger's yard.

33635. You mean that the putrefaction would not yet have arisen ?—Not to any extent.

33636. But it would arise ?—It would arise, because you have got soluble gelatines or gelatones ; you have gelatines in solution, and where you have them in solution and exposed to air, it is bound to undergo putrefaction.

33637. Very well, we have reached this point, that when the waste waters have been reduced in their foulness by reasonable wisdom on the part of the manufacturer in his treatment of the skins, you would still have to carry out some sort of treatment before it would be justifiable to allow such an effluent to flow into the stream. Can you suggest to us what should be done ?—You would mean now an open stream, would you not ?

33638. We are not talking about waste waters going into the sewers ; we are talking about waste waters that go into streams ; what could be done with fellmongers' waste waters after they have been improved as far as they can ?—Only settling, I think. I do not see that it would be any benefit to try and take out all the soluble gelatine. It would be splendid food for fish ; splendid for a trout stream, or anything of that kind, and where you have a fellmonger discharging, you generally have very good fishing on a small river.

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33639. (*Chairman.*) Is the trouble of discharging the ordinary waste of fellmongering very great ?—A fellmonger would do perhaps two to five thousand dozen skins a week. He might have 5,000 to 10,000 gallons of effluent every week, or rather more ; 10,000 to 15,000 ; I should say a thousand gallons a week ; it is not very big.

33640. The amount is not very large ?—No.

33641. (*Colonel Harding.*) But you have suggested to us it would be possible, by the processes you have mentioned, to purify these waste waters ?—Yes.

33642. Can you give us any instance where it has been done on a profitable scale in this country ?—Not in this country.

33643. Can you in any country ?—No, Sir, I do not know of any place where it is being done ; the only thing is, gradually many of these fellmongers have undoubtedly in these last five years improved their process because of the greater activity of the Medical Officer of Health in many cases.

33644. That has reduced the foulness ?—To a certain extent.

33645. That has been by improving their own treatment ; it has not been by any attempt at purification of the waste waters themselves ?—No.

33646. They have improved the waste waters by improving their own processes, probably to their own advantage ?—Yes, undoubtedly.

33647. But you do think, do you not, that it would be financially practicable for fellmongers to improve the waste waters ?—Yes, Sir. They could improve them chiefly by settling, and by not using their liquors over and over again as they do at present, and therefore not allowing them to get so foul and putrid as they do now.

33648. I am rather surprised to find you do not know a single instance where this has been done ?—Oh, I know where settling tanks have been used.

33649. By fellmongers ?—By fellmongers, yes, but most of them have been forced to put in settling tanks within the last twenty years.

33650. What kind of a result does that bring about ; you still have a highly putrefactive liquid ?—Yes, well, you get a more or less clear liquid running down the stream.

33651. But it is highly putrefactive ?—It is highly putrefactive. Needless to say, when there are rains, the foreman comes in the middle of the night and lets the tank go.

33652. But the tank must go sometimes, must it not ?—They are supposed to allow it to settle, and every so often clear it out and cart it away, sometimes it is flushed out.

33653. How is it flushed out ?—That is done sometimes in the middle of the night, after heavy rains when a flood is coming down the streams, wherever it can be done it is done. That is human nature ; it saves £10 or so, the cost of clearing out the tank.

33654. Are we to take it that that is the ethics of all that trade ?—It is not a case of ethics.

33655. You said it was human nature ?—Well, I think it is, when you have a chance ; the stream is high ; there is a great quantity of water coming down, carrying mud and everything else ; they think their liquor will then purify it ; they let it go with it. Perhaps I ought not to have put that in evidence, but it is done, and you must remember, as I told you before, the fellmonger is a small man, and perhaps his idea of what he ought to do, or ought not to do, is not quite so high as yours.

33656. Are these fellmongers in groups, or widely separated ?—Widely separated all over.

33657. There is no possibility of grouping a number of them ?—You might find a couple in a town.

33658. (*Mr. Tatton.*) In the case of fellmongers, would there not be a good deal of waste that goes away that they

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could not improve. For instance, when they scrape the skins, what they call fleshing ?—Then the fleshings are valuable; they are sold to the glue and gelatine manufacturers to make gelatine.

33659. Do not those go down stream ?—No; that must all be kept, because that is valuable. No, it is insoluble. You see, when they scrape it off with a knife, that is all preserved; that fetches something like £5 a ton.

33660. Have they not water playing on it ?—Yes, but nothing runs away except the blood; the blood, the salt, soluble matters of that kind.

33661. Does not water play on the skins, when they are scraping them ?—No, Sir, only the lime salts would be more or less soluble; the gelatine substances would be more or less insoluble.

33662. But the water flowing over it would take a good deal of the smaller portions of the fleshings. I understand they keep back the general part of the fleshings ?—Yes; but there is not sufficient water spraying on it during that period, and the man would be up to that; if he found the solids were running away he would put in some grating to prevent it, because that is expensive material.

33663. But you do get a very bad liquor from that ?—Yes, but that could go through the settling tank with the other liquors.

33664. But that goes away fresh ?—That goes away fresh as a general rule.

33665. Supposing that went into a stream, the solid matter would settle out in stagnant places ?—Yes, in a stagnant pool.

33666. It would set up a very foul liquor ?—Very foul indeed.

33667. Could they treat that by means of settling tanks ?—Oh, undoubtedly they could go through settling tanks and filter beds. Filter beds could be put down where there was sufficient space to prevent all these little finely separated solids running away, to intercept those. It could be put through intercepting filter beds.

33668. Tanks first, and then filter beds ?—Tanks first, and then filter beds; again you must remember that requires space in the country.

33669. Quite so. When you say it requires space, can you tell me at all what space in proportion to the daily out-flow of water. I mean to say would it require tanks large enough to hold one day's supply or two days' supply ? —You would want tanks that would hold at least a 12 hours' supply; this stuff does not settle quickly.

33670. Do they work night and day ?—No; sometimes if they have a pit full of skins, the fellmonger might have bought some skins from a market, and they are liable to putrefaction, therefore he might dip them into water at night; there may be a lot of blood there; he may leave a tap running all night. It is quite a common occurrence, in summer especially of course. By the time he comes in the morning these skins are more or less washed. In those cases there would be some running at night.

33671. And, of course, that would want treating too ?—That would want treating too; I do not know whether it would; washing skins with a little blood in them, there would be so much water and so little blood, that I do not think any Local Authority would make any trouble over that liquor; it is the lime liquors and the putrefactive liquors that you worry over; the washed liquors you would have to run away. I do not think they bother about them, because they would be so weak.

33672. Why do you think the tanners have done more to purify their waste liquor than the fellmongers ?—The ordinary sized tannery would do 5,000 gallons a day, sometimes 10,000 gallons a day, whereas a fellmonger might not have that in the whole week. And then, another reason why I think the tanner has had to do more is because he has tanned effluent and lime effluent, and when the two go together they make a dirty, nasty, sticky sludge. Of course, if that gets down the sewers it is objected to, because it naturally sticks to the sides of the sewers, and consequently they want cleaning out frequently.

33673. Do you know the fellmongers in Lancashire ?—You have picked upon the very district where the best fellmongers exist. The Lancashire and Yorkshire and Scotch fellmongers are more or less up-to-date; they are good men and they are men of standing commercially; Illingworth, and people like that. The Illingworth's have a very big fellmongering establishment. When you deal with those men you have up-to-date fellmongers' yards, and their effluent is not bad. It is when you get the small country fellmonger in little villages away from towns where no progress has been made, then one has trouble.

33674. What is their effluent that is not bad ?—Their effluent is not bad compared with the others. They use their materials fresher, and do not allow putrefaction to go on.

33675. Do you know the works at Milnrow personally ? —No, not personally; I know its product well; I have handled many dozens.

33676. Are these small tanneries in the country ? I suppose, as a rule, they go into small streams ? You spoke of their being little tanneries that you would hardly consider ?—They go into small streams.

33677. And, of course, in these small streams they cause a good deal of trouble ?—In many cases. There are cases where a tanner has had to put in his own drain through these fields; instead of going into the open stream, he has laid a drain to carry that to the bigger stream where he has had no trouble. Take a case in Penketh for instance, my family's old yard—it is some thirty years ago now—they used to discharge the effluent then into a stream which ran down, finally going into the River Mersey near Warrington. The authorities objected to that, and then we put in settling tanks, large settling tanks. They got a three-acre field to put down huge settling tanks. Then, it was further objected to by the farmer who said some of his cattle had gone off milk, or something of that sort, because they had been drinking this water, and the authorities came down and said you must do more. Well, rather than be bothered with it, they built their own drain, and they put 3½ miles of 3-foot drain to the Mersey at high tide. The trouble has gone, till the Mersey people come, at any rate, which I suppose they may do some day. But I do not think they will; it is not a very clean river.

33678. If you have not a Mersey handy ?—That is true. That has been done in another case at Kenilworth, running into a stream. The Urban District Council stopped them and said they must do something. They put down a drain-pipe for three quarters of a mile to a larger stream eventually running into a river. The stream it runs into is 6 feet wide, a big stream. I suppose cattle do not drink from it, so they have no trouble. Still, trouble may come even one day there.

33679. Are there any places you could tell us of where we could get samples just to try the effect, where you think that the works are pretty carefully done ?—I could get you as many samples as you want. I can put you direct in touch with them, but I think I would get the samples better, if you do not get in touch with them. They do not know what you are doing; if they think you are hatching more trouble for them they will not help you. I could get you any samples, typical samples, in any quantity.

33680. Of all the different kinds of effluent ?—Of all the different kinds of effluent. I shall have no difficulty in that, and shall be glad to do it.

33681. Thank you very much. When you speak of reducing the solid matter in the effluent to three parts per 100,000, would that be by settlement alone, or would that include filtration; would they be able to do that just by settlement tanks and precipitation only ?—I should think so; I should think it is possible if large enough.

33682. Without filtration ?—Mind you, you are going pretty low, three parts per 100,000; it is too low a figure.

33683. It is the figure which was suggested to you ?—Yes, I know it was suggested. It sounds to me very low. If you allow it to flow slowly enough, and have sufficient settling tanks, you could get it down to that.

33684. By settling alone ?—By settling alone. Then you can go further, of course, by precipitation.

33685. Or filtration or both ?—Or filtration or both.

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33686. You mentioned works abroad; they are ahead of us, are they, in regard to treatment of the waste?—I think they are perhaps a little.

33687. Why is that; is more pressure brought to bear upon them?—No, I think that the average German, when he gets a problem of this sort, goes to the best man who can advise him, and will follow his advice. He will go to the Professor at the University and say what is your advice, and he will do it. He will not go and digest it and do something quite different, as they do in this country very often.

33688. (*Mr. Willis.*) There was only one question; you said to Colonel Harding that you thought it would be financially practicable for the fellmonger to purify his liquids. I was not quite sure whether by that you meant that it would be financially practicable for him, not only to settle them, but afterwards to pass them through filters of sufficient capacity really to purify, not merely to strain. I do not know whether you know the sorts of filters I have got in my mind?—I do not think it would be to purify; it would be to strain; I should modify that; I should say it would be commercially possible for him to settle his liquors, very heavy sediment, to pass that through filters to strain, but I do not know whether he could purify that unless he were to put down a bacterial bed. Of course, in the Birmingham District, they take the fellmongers effluent on the big Birmingham Sewage Farm and they like it.

33689. And they treat it with the sewage?—They like it because of its nitrogeneous matter.

33690. But there are some cases where it is not possible to put it into a sewer, the fellmonger's works may be away in the country?—Yes.

33691. The same with the tanner. There the man has to do something himself, or discharge it in an unpurified state into the stream?—That is so.

33692. And you think it would really destroy the industry in some of these country places, if you imposed an obligation on a man, not only to strain, but to filter, so that he turned out ultimately something that was non-putrescible?—Yes, I think you would put such a charge on his works that he could not compete with his neighbour who might be more favourably situated.

33693. I suppose you are saying that on general grounds?—On general grounds.

33694. You have not worked it out in detail, what it would cost him, or have you?—No, I have not worked it out in detail, but I imagine to do a thing of this nature from what it costs in tan-yards, that I do not suppose any fellmonger could put up a satisfactory plant under £500.

33695. That would depend on the volume of trade he has?—That is so. I am taking £500 as a round average; I do not think he could find the £500, many of them.

33696. It is difficult for him to find the capital?—Very difficult indeed; many of these fellmongers are men who are not worth £500 altogether; they are small men.

33697. And so far as you are aware, in no case are they passing it through filters and turning out a non-putrescible effluent?—No.

33698. You are not aware of any place where they are doing that?—No, not where they are producing a non-putrescible effluent.

33699. Illingworth's effluent, you said, was very good, but that is not a non-putrescible effluent?—It is not; I believe it runs direct into the sewer, but I am not certain.

33700-1-2. Do your remarks apply to tanners as well? Do you think, in many instances, it would not be possible for the fellmonger to put up the £500, or the money necessary to erect the plant? Would you say the same for tanners?—No.

33703. They could find the capital?—Yes, tanners always say they are poor.

33704. Then there is the further question, have they a sufficient margin of profit to stand this continual charge, because you have got not only the capital to provide the filter plant, but you have got the maintenance of it?—Oh, yes. Tanners could do that; it would handicap one tanner against his neighbour who had not to do it.

33705. But you would say it would not be unreasonable to impose that obligation on tanners, looking at it from a business point of view?—No, it would not be unreasonable.

33706. That is to say where the effluent went into a stream, and it was necessary to purify it?—Yes.

33707. And by purifying, I mean producing something which was non-putrescible and free from solids?—Yes.

33708. Are you aware of any tannery where that is being done now, a non-putrescible effluent is being produced?—No; I will not say in any case a non-putrescible effluent, but settled.

33709. Settled and strained?—Settled and strained.

33710. But not an effluent which has undergone real organic change so as to become inorganic?—No.

33711. (*Chairman.*) There is only one other point, about gelatine works; you mentioned it in passing, and you said they turned out a very bad effluent indeed?—Yes.

33712. Are any efforts being made to treat that?—Only by settling, sir.

33713. No bacterial filtration?—No, I know of no place in England where they are using this bacterial treatment at all for tannery effluent. I might, perhaps if I may, just give you one instance of one of the difficulties that leather manufacturers have to deal with. There is a certain firm, Percy Fisher is the name of the firm, in Godalming; he found the works were not quite suited for his purpose, his lease fell in, he could not come to very good terms; he was up to buy a factory anywhere round London and build a new factory, or adapt a factory, where he would employ about 200 hands. He went round various parts, wherever things were offered to him, and his first duty, or his first problem, was to find what he could do with his effluent, and he was refused in four different districts, but was encouraged by the authorities to come. When he came to speak to the chemist or the engineer, and tried to get them to give a guarantee that they would take his effluent under certain conditions, he could not get that in any case. He has now got a place at Basingstoke. Analyses of his effluents for years were sent to these authorities, and they would give him no guarantee, no permanent guarantee, that they would treat his effluent, while they would take it at present under our present conditions. "Then, will you come to me in five years, and want something altering?" He would not go till he could get a guarantee that they would take his effluent under certain conditions, free of solids. He has put down settling tanks at Basingstoke, where he has only opened last month. It took him nearly a year to get a place. He had almost come to terms at Lenham; he had paid his deposit money, but he would not fix the matter up, the transfer of his plant until he got a guarantee. "That effluent must be so and so; when it is so and so we will take it." They said, "No, we do not see any objection to your effluent at present as it exists at Godalming. They took samples; he was not to allow any free acids, and he was to provide a more or less neutral effluent with no free acid in it. At present, in no place will he get a permanent guarantee. "In five years time I may have to spend £1,000 possibly." "We hope not." They would not give a guarantee. It would be such an advantage, I want to impress upon you, to the trade if they only knew where they were in matters of that sort, and if it could be understood that these Urban District Councils were to lay down a certain rule and stick to it, say after ten years, or twenty years, or something of that kind, it would give peace. I may tell you frankly that in two cases where there was difficulty with an Urban District Council I went down and advised the tanner, and helped them in various things. We get so much trouble that my universal remedy now is for the tanner to get elected on the Urban District Council, and the trouble has ceased. I have at the present time one man in my mind, after spending £2,000—he is now Chairman of the Urban District Council; he has been for the last six years—he has naturally had no trouble.

33714. We are very much obliged to you for giving us this evidence.

ONE HUNDRED AND FIFTH DAY.

Monday, 17th November, 1913.

PRESENT:

Sir WILLIAM RAMSAY, K.C.B., F.R.S. (*in the Chair*).
Colonel T. W. HARDING, J.P., D.L.
Mr. R. A. TATTON, M.Inst.C.E.
Mr. F. J. WILLIS.
Mr. R. H. H. KEENLYSIDE (*Secretary*).

ALSO PRESENT:

Dr. GEORGE MCGOWAN.
Mr. C. C. FRYE.
Mr. G. B. KERSHAW.

Mr. A. POOLE WILSON (Inspector of Dairying in the Department of Agriculture and Technical Instruction for Ireland), called in; and Examined.

Mr. A. Poole Wilson.

17 Nov., 1913.

33715. (*Chairman.*) You are Inspector of Dairying in the Department of Agriculture and Technical Instruction for Ireland?—Quite so.

33716. You have been kind enough to send in a statement of the export of dairy produce from Ireland in 1912, both as to quantity and value, and the various arrangements for the manufacture of butter at the farms and creameries, for the disposal of butter, and the situation of creameries and butter factories. I suppose this situation has arisen accidentally, as it happened to suit the farmers in the neighbourhood; is that so? The situation of creameries and butter factories?—The creamery was placed where the greatest number of farmers could send their milk with convenience. For instance, take the Ordnance Map, find some spot in the district towards which all the roads tend, and erect a creamery to suit the majority of the farmers who intend to send their milk to the creamery.

33717. Would it be very difficult to change their localities supposing there were no facilities for drainage whatever?—It would mean giving up the land and buildings.

33718. Which are pretty costly, I suppose?—They are; I mean costly from their point of view; it might not be costly from other people's point of view, but they would lose their capital, amounting to £800 to £2,000.

33719. Who are "they"; the farmers in the neighbourhood?—Generally speaking, the farmers in the neighbourhood. Of course, as I mention in my statement, creameries in Ireland are divided between proprietors and co-operators. The co-operative creameries are in the majority now, and the proprietary concerns are gradually dropping out, so that when I use the term "they" I mean the farmers.

33720. Then do they pay *pro rata*; may they take any number of shares they like, or is the payment *pro rata* according to the amount of milk they send in?—The number of shares which a man can take in the creamery is limited by the provisions of one of the Acts dealing with Industrial and Provident Societies; I think the Act of 1893. I do not remember the exact number of shares that he must not exceed, but the farmer sending his milk to a creamery is generally paid per lb. of butter fat in the majority of cases; I do not say all; and that is irrespective of the fact whether they may be shareholders or not in the concern.

33721. They need not be shareholders?—Some creameries will take milk from anyone, whether they are shareholders or not; others will take only from shareholders.

33722. So if the situation of these creameries had to be changed it would affect mostly shareholders?—It would, and a few of the farmers that were sending milk might be further away from the new site than from the old site, so it would affect them to the extent that the time involved in the cartage to the creamery would be longer. Of course, where milk was collected, that might not be a serious item.

33723. You say there is no objection to discharging crude waste liquors into sewers. I do not see why an objection should be raised; but are there many creameries within reach of sewers?—Very few. Out of 398 creameries from which we received information, I found there were only 16 discharging into village or town sewers. Are you intending to reproduce my *précis*, or do you just want to question me on certain points?

33724. (*Colonel Harding.*) It is a very terse and useful document. I suggest it be reproduced, and in that case we need not ask many questions?—It would save me putting points before you, if you reproduce it, I think.

SUMMARY OF EVIDENCE OF MR. A. POOLE WILSON, INSPECTOR OF DAIRYING IN THE DEPARTMENT OF AGRICULTURE AND TECHNICAL INSTRUCTION FOR IRELAND.

DISPOSAL OF TRADE WASTE FROM CREAMERIES, ETC.

Extent and Character of Industry.

The export of dairy produce from Ireland in 1912 was as follows:—

	Quantity.	Value.
	cwts.	£
Butter - - - - - -	778,778	4,159,972
Cheese - - - - - -	10,260	32,832
Condensed milk - - -	246,723	326,908
Whole and separated milk -	5,271	1,779
Cream - - - - - -	13,016	37,258

This does not include the export trade by parcel post, or the parcel service by fast passenger train, branches of the trade which appear to be on the increase.

Butter is manufactured in Ireland—

(1) At the farm;

(2) At the creamery.

In the case of (1) the butter may be sold—

(*a*) To butter factories, where it is blended and constitutes what is known in the trade as factory butter. This accounts for the greater part of the butter made on farms;

(*b*) Direct to consumers by parcel post or rail;

(*c*) To agents or grocers.

A creamery is a place to which surrounding farmers send milk to be manufactured into butter.

A cream-separating station is a place to which the surrounding farmers send milk to be separated, the cream being then sent to a creamery to be churned and marketed.

According to the Census of Production, 1907, there were 670,000 cwts. of butter, valued at £3,551,000, made in creameries or blended in butter factories. About three-fourths of this quantity was made in the creameries, and about one-fourth blended in butter factories.

Situation of Creameries and Butter Factories.

Creameries and cream-separating stations are in most cases situated in country districts at convenient cross-roads. A few are in small villages, and a still smaller number in country towns. There are about 800 creameries and cream-separating stations at present, and the number is increasing. They produce our finest butter.

Most of the large butter factories are situated in the city of Cork. A number are also scattered through the smaller country towns in Ireland.

Discharging the Crude Waste Liquors into Town Sewers.

Factories.—In the case of butter factories, no complaints have been brought to the notice of the Department that the discharge of waste liquors into the town sewers has been objected to on the part of the local authorities.

Creameries, etc.—The only case of which the Department have any knowledge where the local authorities objected to the discharge of trade refuse from a creamery into the town sewers was at Mitchelstown. The Rural District Council had put down a sewage purification plant which apparently did not give satisfaction. The local creamery was blamed ,and action was taken by the Council, as the Sanitary Authority, against the owners of the creamery. The proceedings were taken under Sections 16 and 17 of the Public Health Acts Amendment Act of 1890. The charge under Section 16 was not proceeded with, the complainants relying on Section 17 (1) (*a*). The case was dismissed.

Enquiries into the methods of disposal at 398 creameries and cream-separating stations elicited the following information :—

Discharged into the village or town sewer	16
Carted away - - - - - - -	3
Discharged by gravitation or pumped over land - - - - - - - -	21
Discharged into a river or stream - -	310
Discharged into a dry ditch or bog - -	33
Discharged into a septic tank - - -	8
Discharged into a septic tank, with subsequent treatment in bacterial beds - -	7
	398

Trouble Arising out of Discharge of Trade Liquors.

Injunctions for pollution and claims for alleged damage to cattle are increasing. In the words of a correspondent : "It has got to be the fashion now for farmers and others to bring actions against creameries for real or fancied injury to their live-stock by drinking water into which the washings of a creamery have been discharged."

Complaints have been made in about 50 of the 398 places referred to above. There is no doubt that many complaints of which the Department may hear nothing have been settled privately by making payment or conveying the refuse beyond a complainant's land.

Description of Several Branches of Dairying.

At a cream-separating station the farmers deliver their milk. The milk is weighed and strained ; it is then heated to from 120° to 195° in a machine and conveyed to the separators, the cream being cooled and collected in cans for conveyance to the churning centre. The separated milk may be cooled, and is then returned to the farmers in proportion to the milk delivered.

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Butter-Making.

At a creamery, in addition to the above work, the cream, after cooling, is soured, with or without the addition of a starter and, when sour, cooled to the churning temperature. After churning, when the butter is in a granular condition, the buttermilk is drawn off and pumped into a tank, from which it is delivered to the suppliers.

The granules of the butter may then be washed with water once, twice, and, in a few cases, three times. The butter is then "worked" on a rotary butter-worker till ready for packing.

Cheese-Making.

After the reception of the milk as above it is renetted at a suitable temperature. When the curd is sufficiently firm it is cut. The separation of the whey is further aided in some cases by heating.

The whey is drawn off and may be returned to the farmers or run into the drain.

The curd is further handled, salted and put into press.

Condensing.

The milk is heated, sugar added, and evaporated down to about one-third of its volume in a vacuum pan. It is then cooled and tinned.

Quantity of Trade Refuse.

It is a difficult matter to apportion the quantity of trade refuse to each individual stage of manufacture. All the processes may be conducted in the one room, or some portions of the premises may be more difficult to clean than others, involving the use of more water for cleansing purposes.

The trade refuse consists of :—

(1) Rain-water from roofs and the clean water used for cooling the milk, cream, separated milk, or the condenser of a refrigerating machine.

(2) Water used in washing down the premises.

(3) The washings from the various machines, such as separators, coolers, churns, butter-workers, tanks or vats for the new milk, cream, separated milk, buttermilk and whey, the pipes or chutes used for conveying any of the milky liquids and the rinsings of farmers' cans.

No. (1) can be diverted from the rest of the refuse, and delivered in a clean condition to a stream or river.

Excluding the clean water, it has been found that the trade refuse from a cream separating station or creamery varies from one-third to five-sixths of the total quantity of milk treated directly or indirectly at the premises.

The refuse from a cream-separating station receiving 1,000 gallons of milk daily is about 300 gallons. Washing the butter and then the cream vats, churns and butter-worker would yield about 400 gallons, and cleansing the churning-room about another 100 gallons ; making 800 gallons of refuse from a creamery receiving 1,000 gallons of milk.

The refuse when running from a creamery is in appearance milky water.

The analyses of a few typical samples of trade refuse from creameries are given below. Some of these are samples from the bulk, and some by dipping from the drain, as far as possible in proportion to the flow.

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TRADE REFUSE FROM CREAMERIES.

	Parts per 100,000.						
	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)
Total solids - - - - - -	1,053	881	883·4	315*	488	1,123†	521
Solids in suspension - - - - -	208	188·4	253	76	214	264	142
Solids in solution - - - - - -	845	693	630·4	239	274	859	379
Loss in ignition - - - - - -	754	601	604	—	—	—	—
Saline ammonia - - - - - -	2·25	2·7	2·17	2·00	0·96	2·86	1·0
Albuminoid ammonia - - - - -	32·1	29·5	33·0	9·33	5·3	15·0	8·0
Total organic ammonia - - -	42·6	40·9	42·0	—	—	—	—
Oxygen absorbed from $\frac{N}{8}$ permanganate at 80° F.:—							
In 3 minutes - - - - -	23·3	129·5	66·4	4·68	17·6	23·15	19·8
In 4 hours - - - - - -	168	195·6	200	14·15	91·5	472·5	140·0

* This sewage was diluted with a quantity of water from a condenser and the oxygen absorption determined by $\frac{N}{80}$ permanganate.

† This sewage contains some whey from cheese-making.

The oxygen absorption of some of the individual portions of which the sewage is made up is as follows:—

	Oxygen absorption in 4 hours at 80° F. from $\frac{N}{8}$ permanganate.
	Parts per 100,000.
First washings of butter from churn (4 samples) - - - -	189–250
Second washings (2 samples) - -	56–85
Washings from separated milk tank	169
Washings from butter-milk tank -	173

The sewage is, therefore, a difficult one to treat, and contains matter of a gelatinous and colloidal nature.

It contains small quantities of fat, casein compounds, albumen, milk sugar and lactic acid.

Irregularity in Quantity of Sewage.

There is also the further difficulty that the flow of sewage is at its maximum in the summer months, when the streams into which it may be discharged are at their lowest. Thus any scheme of purification has to be designed to deal with the maximum summer flow.

Lack of Capital for Extension Plant.

Most of the creameries belong to the farmers, who have not much capital to spare for the erection of elaborate plant for the purification of the refuse.

Unfortunately, in many cases, the site selected for the creamery was not always chosen for its suitability in disposing of the refuse in those cases where purification to some extent would become necessary. The Department have drawn the attention of promoters to this matter through their Instructors in Dairying and their leaflet on Creamery Buildings.

Experiments and Plants put down.

The first attempts at purifying this class of refuse were made in 1893, by filtration through peat, cinders, clinkers or sand, but a few days' flow was sufficient to choke any filter, and the effluent caused as much trouble as the original refuse. Various precipitation methods were attempted, using lime with or without salts of iron, alumina, etc., the best precipitant being a per-salt of iron used by silk-dyers. All were, however, failures, the effluent being highly putrescible, and giving equal trouble to the raw refuse, and great trouble and expense was entailed in dealing with the sludge.

The Oxygen Purification Company (now, it is believed, defunct) tried to purify the sewage and failed.

Irrigation was also tried, both with and without willow-growing. Where the land available was sufficient, of a suitable nature, and a good distance away from a public road or habitations, the method was successful in dry seasons, but in wet seasons pools of decomposing sewage formed, and there was a strong stench which carried to considerable distance.

In 1902 the Department made enquiries into the matter, and finally undertook to carry out experiments. The creamery selected for these experiments was one which was in a most difficult position as regards facilities for the erection of purification works. It was at that time threatened with closing-down on account of the pollution of a stream.

The following were the ideas on which the experiments were initiated:—

(1) The method of treatment should involve the smallest possible capital outlay.

(2) The cost of running should be small.

(3) It should require very little attention, and only such as could be given by a country handyman.

A septic tank with a capacity of seven times the maximum flow expected and two bacterial contact beds were put down, the first being filled with coke, and the second with gravel, ranging from three-eights to one inch.

It was found that the quantity of sewage had been under-estimated, and that the septic tank only held about two to three days' flow

The average of the oxygen absorption figures for four hours at 80° F., using $\frac{N}{8}$ permanganate, was:—

	Parts per 100,000.
Raw sewage - - - - - -	180·7
Effluent from septic tank - -	48·0
Effluent from contact beds - -	12·7

The method of working was as follows:—

The fresh sewage displaced an equal quantity from the septic tank which was collected during the day in the first contact bed. In the evening, a few hours after all work had stopped, the contents of the first contact bed were discharged into the second, and remained there overnight, being discharged into the stream first thing next morning. The effluent was slightly putrescent, had a very faint odour, in which an earthy smell predominated, and in appearance was slightly opalescent. The sludge was removed at the end of the year, when all other work was slack.

The contact beds were then converted into additional septic tanks, very much improved results being obtained,

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the septic tanks holding from seven to ten days' flow of sewage. It was further noted that at the beginning of the season, when the tanks had just been emptied, and the flow of sewage was small, the effluent was always much better, this being apparently due to the fact that the sewage remained longer in the septic tank.

A percolating bed with a Stoddart distributor was tried in the place of the contact beds. This, however, was a failure. The clinker broke down, and the distributor was unable to deal with the irregular flow of sewage. The percolating bed also gave off a stench which put it out of the question if there were roads or habitations near.

The results were as follows:—

	Oxygen absorbed in 4 hours at 80° F. from $\frac{N}{8}$ permanganate.
Effluent from septic tank - -	19·4
Effluent from percolating bed -	14·7

Two contact beds, both filled with limestone of the size of road-metal, were substituted for the percolating bed, the idea of using the limestone being, firstly, that it was a material found all over the country, and thus easily available; secondly, that it would neutralise the acidity of the effluent from the septic tank.

During this period the first washings from the churn were pumped into a tank, allowed to settle, and the curdy matter given to farmers for pig-feeding, the supernatant liquor being discharged into the drain. The effect of this on the effluent from the septic tank is shown by the following figures:—

	Oxygen absorbed in 4 hours at 80° F. from $\frac{N}{8}$ permanganate.
Effluent from septic tank - -	10 (7·3–17·4)
Effluent from contact beds - -	5·1 (3·8– 6·6)

At this stage the results were satisfactory to the creamery, and as the Department had demonstrated that it was possible to purify the effluent, the experiment was not carried further, the company repaying to the Department a proportion of the estimated cost of the works.

The stream, which had been formerly white with the sewage for about a mile, and nothing but an open septic tank, was again quite clear, and showed none of the usual signs of pollution.

The creamery is still using the plant, but owing to increased business they have had to add another septic tank, and in all likelihood they will require yet another such tank shortly.

Since then several septic tanks have been put down, and in some cases bacterial beds.

The Department at present advise as follows:—

If disposal by irrigation is not possible, or is too costly, then a covered septic tank capable of holding about seven to fourteen days' maximum flow of sewage, according to its quality, should be used.

If the effluent from this tank is not sufficiently pure, a contact bed should be provided and filled with limestone chippings, three-eights to three-fourths of an inch, such as can be obtained from any stone-crushing machine. If effluent is not yet sufficiently pure, then either another contact bed or a percolating bed should be added, a sludge pit being provided to hold the sludge from the septic tank at the close of the year.

Other Plants.

Several plants have been since put down on plans supplied by sewage engineering firms.

In one case the engineer who had considerable experience of sewage works, asserted that the Department had been over-septicising the sewage. His plant, however, worked so unsatisfactorily that it was removed, the trouble, so far as could be ascertained, being that the septic tank capacity was too small, and the siphons were always giving trouble.

In five other cases the addition of increased septic tank accommodation to plants put down by sewage engineering firms gave good results when the previous results had been most unsatisfactory.

Slate beds have been tried at a few places, but did not satisfy the people who put them down, as they speedily choked.

In another place, where the plant consisted of a collecting tank, two parallel contact beds and then two parallel percolating beds, with automatic siphons and revolving sprinklers, the failure of the plant was prevented by adding large septic tank accommodation, and the results proved very satisfactory.

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TABLE I.

RESULTS OF OXYGEN ABSORPTION TEST IN FOUR HOURS AT 80° F. USING $\frac{N}{8}$ PERMANGANATE. SAMPLES EXAMINED AT TWELVE HOURS AFTER TAKING. SOLIDS IN SUSPENSION INCLUDED.

Parts per 100,000.

Date. 1912.	Fresh sewage taken at trap.	After settlement in tank.		Flowing on to contact beds.		Flowing from contact beds. Two hours contact.		Flowing from percolating beds.	
		For hours.		Clinker.	Limestone.	Clinker.	Limestone.	Bed fed from clinker contact bed.	Bed fed from limestone contact bed.
October 7th - - -	107·8	—	—	—	—	—	—	—	—
,, 8th - - -	102·5	48	67·14	77·41	65·87	42·77	46·61	2·31	3·15
,, 9th - - -	65·04	48	63·00	59·79	65·26	29·67	53·40	3·24	3·97
,, 10th - - -	68·47	55	50·20	44·73	53·86	28·76	48·39	2·10	3·20
,, 11th - - -	68·00	—	—	—	—	—	—	—	—
,, 12th - - -	127·17	48	63·19	69·61	66·80	21·73	39·84	3·06	3·61
,, 14th - - -	76·24	15	99·20	64·76	62·00	41·80	50·97	2·11	2·20
,, 16th - - -	74·63	48	52·20	54·49	62·73	39·83	53·11	1·02	1·30
,, 17th - - -	43·04	60	36·63	40·29	40·76	29·76	32·97	0·91	1·10
,, 18th - - -	65·50	60	31·84	35·03	32·76	25·03	26·84	1·14	1·54
,, 19th - - -	103·74	50	36·29	34·93	32·66	20·86	22·23	0·73	2·04
,, 21st - - -	104·69	48	47·17	36·84	28·76	22·91	25·61	2·29	3·41
,, 22nd - - -	73·44	60	40·32	45·23	38·07	24·63	24·19	0·71	1·16
,, 28th - - -	78·37	60	34·04	33·59	29·11	22·84	23·29	0·86	1·11
,, 31st - - -	77·67			No Further samples taken on those days.					
November 1st - - -	106·69								
,, 2nd - -	81·06	48	53·30	42·54	45·69	17·47	27·32	2·96	2·73

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TABLE II.

CREAMERY SEWAGE PURIFICATION.

DETERMINATION OF THE OXYGEN ABSORBED FROM $\frac{N}{8}$ PERMANGANATE IN FOUR HOURS AT 80° F. ALL SAMPLES ARE COMPOSITE AND COVER THE DAY'S WORK.

FIGURES GIVE PARTS PER 100,000. MATTER IN SUSPENSION IS INCLUDED.

1913.	Raw sewage taken at trap.§	Effluent as it leaves the three sections of the septic tank.			Effluent flowing from collecting tank on to		Effluent from contact beds.		Effluent leaving percolating beds.		
		1st section.	2nd section.	3rd section.*	Clinker contact bed.	Stone contact bed.	Clinker Bed.	Limestone Bed.	Bed receiving effluent from clinker bed.	Bed receiving effluent from limestone bed.	
April 9th	—	—	—	—	5·01	5·47	4·11	3·65	0·95	1·00	—
„ 10th	—	—	—	—	6·64	6·80	5·50	6·14	1·81	0·87	—
„ 11th	—	—	—	—	5·63	5·75	5·25	5·44	1·04	1·17	—
„ 18th	—	—	—	—	6·24	6·41	5·80	6·18	1·13	1·35	—
„ 21st	—	—	—	—	5·97	5·34	5·53	4·90	1·07	0·71	—
„ 24th	45·83	9·34	6·67	—	5·21	5·30	4·70	4·90	0·93	0·63	—
„ 28th	79·67	7·25	5·94	—	5·13	5·31	4·58	5·00	0·46	0·83	—
May 5th	60·44	7·69	6·77	—	5·67	5·54	4·85	4·94	0·64	0·87	—
„ 9th	90·71	10·90	8·71	—	6·84	6·67	5·98	6·13	1·27	0·95	—
„ 15th	119·73	9·40	8·48	—	7·68	7·64	6·56	7·10	1·75	1·30	—
„ 17th	60·45	10·25	9·23	—	7·26	7·65	6·65	6·75	0·94	1·21	—
„ 20th	93·56	9·91	9·08	—	7·19	7·30	6·27	6·31	0·93	1·01	—
„ 27th	46·90	11·20	10·60	—	8·18	8·18	7·33	7·60	1·00	1·31	—
„ 30th	88·50	11·90	8·54	8·04	7·10	7·25	6·30	6·71	1·70	1·90	—
June 6th	83·57	10·36	9·21	8·86	8·35	7·96	7·69	7·46	1·44	1·39	—
„ 12th	81·76	10·43	8·77	—	8·31	8·21	6·61	7·49	1·89	2·01	—
„ 21st	50·31	—	—	8·59	8·00	8·04	6·96	7·64	1·80	2·60	—
„ 27th	—	—	—	—	7·64	7·97	7·06	7·45	0·64	3·20	—
July 2nd	56·90	10·31	8·69	—	7·64	7·73	6·41	6·56	0·64	1·27	—
„ 14th	124·81	10·24	8·73	8·21	7·64	7·83	6·21	6·60	0·57	0·80	—
„ 22nd	—	11·64	11·01	8·91	8·41	8·41	7·37	7·69	0·73	1·69	—
„ 23rd	—	—	—	—	—	—	—	—	1·54	—	—
„ 24th	50·00	9·69	8·40	8·24	8·07	8·01	7·34	7·39	0·73	2·03	—
„ 30th	127·20	10·43	9·09	8·19	7·66	7·49	6·90	7·01	0·96	0·87	—
August 4th	119·30	10·16	8·70	7·76	7·17	7·30	6·17	6·53	0·50	0·69	—
„ 6th	57·6	9·64	8·40	7·57	7·40	7·17	6·26	6·34	0·46	0·37	*See* Table III. for detailed analyses.
„ 11th	104·3	10·26	9·40	7·26	7·07	7·00	6·26	6·40	0·27	0·24	
„ 19th	39·24	9·09	8·36	7·03	6·80	6·84	5·99	6·34	0·31	0·31	—
Averages											

* The effluent from Septic Tank flows into a collecting tank which feeds the siphons discharging the liquid on to the contact beds.

§ A large quantity of condenser water which had become foul was discharged at irregular intervals into the drains and caused great variations in the quality of the sewage.

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TABLE III.

COMPLETE ANALYSES OF SAMPLES TAKEN ON AUGUST 6TH, 1913, MENTIONED IN TABLE II. SOLIDS IN SUSPENSION ARE INCLUDED IN DETERMINATIONS.

Parts per 100,000.

	Fresh sewage as it enters the septic tank.	Effluent from 1st section of the septic tank.	Effluent from 2nd section of the septic tank.	Effluent from the 3rd section of the septic tank as discharged into collecting tank for feeding siphons.	Effluent running on to the contact bed.		Effluent from the contact beds.		Effluent from the percolating beds.	
	Quantity delivered this day, 20,000 to 25,000 gallons, contained a large proportion of condensing water.	Capacity of each division, 52,000 gallons, giving about eight days' total septicising at this time of the year.					Clinker bed.	Limestone bed.	Fed from Clinker contact bed.	Fed from Limestone contact bed.
					Clinker bed.	Limestone bed.	About two hours' contact and charged about every 3½ hours.		Effluent discharged on to 40 feet diameter beds in 75 minutes.	
Solids in solution - - - -	239·0	125·0	123·0	123·0	117·0	117·0	98·0	102·0	71·0	83·0
Solids in suspension (filtered through paper) - - - - - -	76·0	25·0	15·0	14·0	17·0	16·0	22·0	18·0	5·0	1·0
Free ammonia - - - - -	2·0	10·40	11·20	11·77	10·53	12·50	8·89	8·0	0·14	0·10
Albuminoid ammonia - - - -	9·33	2·00	1·40	1·00	0·90	0·90	1·00	0·90	0·08	0·07
Oxygen absorbed in 3 minutes from $\frac{N}{80}$ permanganate at 80° F. - -	4·68	3·90	3·51	3·06	2·60	2·60	1·69	2·08	0·033	0·075
Oxygen absorbed in 4 hours from $\frac{N}{80}$ permanganate at 80° F. - -	14·15	8·39	6·58	4·61	4·28	4·28	3·95	3·95	0·132	0·099

The difference between the figures for oxygen absorbed in 4 hours in this table and those in Table No. II. may be attributed to:—

In this case $\frac{N}{80}$ permanganate was used.

In other case $\frac{N}{8}$ permanganate was used.

In this case samples were 48 hours old when analysed.

In other case samples were 12 hours old.

33725. (*Chairman.*) Now, you speak of trouble arising out of the discharge of trade effluent; is it known that there is any harm done to cattle by drinking such effluent after it has been treated ?—It has been stated so, but I should not like to say it is known for a fact. For instance, in one case in which I was concerned a number of years ago, a Company I was connected with as Analyst and Expert, were sued for damages for poisoning cattle. The evidence tended to show that the cattle had died of a very common disease, husk or hoose, but the Company had to pay damages to the extent of £500 and costs really for pollution. The case for poisoning cattle has not, to my mind, been made out, because I have seen cattle drinking creamery sewage almost pure and undiluted in a state of more or less decomposition; I have seen that, and I have not heard of the cattle suffering, in fact, I know one case, in the dry summer of 1893, where the fresh sewage from the creamery was used for watering the cattle; they had no other water in the district. Of course, that was fresh, but cattle drank from the little stream into which that flowed, where it was decomposed, and as far as I could see and hear, no harm happened to them.

33726. There is no absolute proof ?—There is no absolute proof to my mind; I have never had a case brought to my notice where it was proved satisfactorily.

33727. Is it known that no special disease germs would grow in such refuse which would be deleterious to cattle ?—That is going a little beyond me. I have not inquired into the growth of disease germs in the sewage, because we were interested in purifying the sewage from purely a commercial point of view; getting the creamery out of trouble, not from the scientific point of view of purifying sewage or obviating the spread of any disease. Of course, if we had suspected it, we would have perhaps gone into the matter, but as far as I understand, the present trend of opinion is that practically no germs of disease can live or do live in these strong sewages, but I do not know whether that is a certainty or not.

33728. Of course, we know that milk is very often the reason for zymotic diseases in human beings ?—Yes.

33729. Such has never been proved, to your knowledge, in cattle ?—That disease has been conveyed by milk ?

33730. That disease has been conveyed by milk to cattle, I mean ?—Oh; I think that has been proved; yes.

33731. You give a very interesting short account of butter-making and cheese-making, and the condensing of milk ?—Well; it was just to make clear the methods that were used in factories.

33732. Would you call rain-water used for cooling the cream or milk, trade refuse; is it made impure ?—No; it is part of the discharge from the creamery, you see. I simply put it in from that point of view; that the liquid discharge from these creameries is largely made up of that. I do not call that polluted; really the water is, you might say, refuse water, but it is not polluted water.

33733. You can hardly call this refuse sewage waste from creameries ?—Refuse; well, the term sewage was applied to it all; although it rather went against my own mind to use the term I thought it was the word most generally used, and kept to it from that point of view.

33734. From the analyses which you give in your statement it would appear that refuse is very polluted; obviously it is very highly organic; there is a large mass of albuminoid ammonia and organic ammonia ?—As far as my experience goes, it is the most difficult sewage I know of to purify.

33735. But it can be purified, I suppose, by the ordinary method of continuous filtration; can it not ?—By the ordinary method of continuous or intermittent filtration ?

33736. Yes—Do you mean actual filtration ?

33737. Actual filtration; exactly in the same manner as sewage is purified ?—Well, it is more contact. I think it is not exactly filtration.

33738. Well, it depends on what you call it; of course it is contact with the filters; put it that way ?—Yes.

33739. It can be purified in that way; can it not ?—Well; we purify it to a certain extent that way, but how far we could go towards the standard suggested in one of your Reports I would not like to say at present, because I would like to have some further analyses made so as to compare them with your standard.

33740. Has any attempt been made at any one of these creameries to treat this refuse as ordinary sewage, and put it through the usual contact process ?—Oh, yes; later on I refer to cases where they put down septic tanks, then contact beds, and in some cases followed by percolating beds.

33741. Has the refuse been greatly diluted before it has been tanked, or has any attempt been made to filter it pure ?—No; we found that by withdrawing all the water used for condensing or cooling purposes and the rain-water, we could diminish the flow of sewage to about one-third, and that it was cheaper to deal with that concentrated sewage than to deal with the vast quantity of dilute sewage.

33742. Have you had personal experience of this septic tank, which you tell us about in your statement ?—I have. Since 1893 I have been more or less connected with attempts to purify creamery sewage, and in the end the Department carried out some experiments on the septic tank principle, followed by treatment in contact, and percolating bacterial beds.

33743. Was there a very heavy deposit in the septic tank ?—There was a larger deposit than we expected. Theoretically, this sewage ought to really decompose and pass away, because there is practically no mineral matter worth talking of in it, but in practice we found that a good deal of the caseous matter settled, and part of it was carried up by the gases given off during decomposition, to form a floating layer. At the end of a year, in a septic tank, we would have perhaps a foot of a paste like lime putty on the surface, and perhaps 18 inches of a thick sludge at the bottom out of a total depth of 6 to 7 feet.

33744. A very large deposit ?—It is a large deposit, but not for the year's working; that is the way we looked at it.

33745. Was that sludge a very disagreeable stuff to remove ?—Well, for instance, it was no more disagreeable to me than the cleaning out of a pigstye, but a good many people who would think perhaps nothing of the cleaning out of a pigstye or a cow-byre, would strongly object to the removal of the creamery sewage.

33746. It is smelly stuff ?—Once you get to know the stuff, you do not mind it.

33747. But I suppose it was dirty ?—It was used as manure in some cases, and put in a pit, and used for mixing in compost heaps and between layers of manure, and it made a very good top dressing.

33748. I see you do not improve the refuse much by filtering through a percolating bed with a sort of distributor ?—We found that rather a failure. Of course, the flow of sewage was slow, and the distributor was not suitable for that.

33749. Did it block up ?—Well, it gradually blocked up, and wanted cleaning, you might say, two or three times in the day, and then the sewage dissolved away the iron.

33750. It is very acid ?—It was very acid. You will see finally we used limestone in our contact beds, and even put large lumps of limestone at the outlet of the septic tanks in order to reduce the acidity, and we found it did that very well. It probably could be done better if you added milk of lime, artificial or mechanical devices being used for adding it in proportion to the acidity of the sewage; but we wanted the simplest method, because the men who deal with these plants were ordinary countrymen who could not be relied on giving, perhaps, the close attention needed to a mechanical device or any intricate scientific method.

33751. There is a very interesting sentence here. You say that "During this period the first washings from the churn were pumped into a tank, allowed to settle, and the curdy matter given to farmers for pig-feeding." The settling was pretty rapid, I suppose ? It would have decomposed if the settling had not been pretty rapid ?—Well, that would be up to 24 hours. There was still a lot of matter in solution and suspension.

33752. Would simple sedimentation of such stuff, separating with a centrifugal machine, bring it down quickly ?—It probably would, but there would be the cost of running.

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33753. But would not that be amply repaid by the value of the stuff as a pig food ?—As a solid; I do not know that it would be a pig food in the solid mass. You see it is a question that wants considering, but it would involve a good deal of expense in putting down a machine and the cost of running.

33754. Have any attempts been made to add something or other to it, such as bran or something of that sort ?—As a food ?

33755. So as to carry it down and make it a food ?—No, not that I am aware of. This thick portion that settled was simply taken away by some of the farmers, and they added Indian meal, or whatever feeding stuff they were using, to it, and gave it to their pigs.

33756. But it might be possible by using some vegetable matter. I do not know whether bran would be the best; but by adding Indian meal, or something of that kind, to it, and settling it together, it might become a very valuable feeding material ?—Well, it might. It is a thing I will think over, but we have not tried it so far, and I would not like to say.

33757. Is it not possible to filter it off through bags or something of that kind, after some substance of that kind has been added, so as to get a material that an animal would eat ?—Well, I have never tried it, so I cannot say whether we could filter it off. I might just say this: that in some cases we filtered off the suspended matter from the sewage, and we found from the purification point of view, the filtrate was nearly as difficult for purification as the sewage was before the solid matter was taken out. It is the sugar, albumen, and soluble bodies formed by the decomposition of the casein which give the greatest trouble.

33758. Then another question: would it be possible to evaporate it ? It appears to be pretty strong, and there is not very much of it; would it not be possible to boil it down ?—The plant, for say a creamery getting 2,000 gallons a day, would be required to evaporate about 1,500 gallons of sewage daily.

33759. Would not its value be greater than that of the coal required to evaporate it ? It would require to be done in vacuo ?—Yes; but a vacuum condenser such as is used in a condensing factory, would cost about £3,000 or £4,000.

33760. Oh, no!—The whole plant, I should think so. I am just speaking off-hand; I will correct the figure later on, but I should think it would run into that. There would be a building for it; the boiler to supply the steam; there is a vacuum pan and pump. I am afraid it would be very costly. One factory that I have in my mind has up to 25,000 gallons of sewage daily, and they have a condensing plant, as it happens.

33761. Do they use it ?—They use it for condensing milk.

33762. For making condensed milk, exactly. I suppose not many of the creameries have such a plant, have they ?—No, very few. I might say there is only one Company in Ireland now condensing, but they have about, I suppose, ten to twenty centres where they condense, and they have, probably, thirty or forty branches from which they collect milk.

33763. It pays, I suppose, if done on a sufficiently large scale ?—Certainly, or I do not think the Company would go on with it.

33764. Do you know the smallest scale on which it would pay ? Would it not pay these other creameries to put in the plant ?—Not unless you had 5,000 to 6,000 gallons of separated milk or pure milk to condense; I do not think it would pay at all. You see you have got to condense the milk, and then you have to find a market for it. It is an easy enough thing to make condensed milk, but to sell it at a profit is one of the hardest things in the world; you have to get into the markets.

33765. There is another plant I know of, the German plant. Mr. Horstman used to let the milk go on to a cylinder, where it dries, and it is scraped off. It makes a sort of milk powder. I know that has a very ready market on the Continent.—Well, we have had some of the machines you describe running in Ireland, and the owners found that the market did not buy the milk powder at a paying rate, and, in fact, firms that put them down, that I thought could have used the powder in their various manufacturing products that they made, have given them up, I believe. The best plant for making a milk powder, unfortunately, we cannot get hold of. It is made in this country alone. We are trying to get it over to Ireland, but we cannot do it just at present.

33766. Is there no way of throwing out the casein you spoke of—casein in solution ?—Well, bodies due to the decomposition of the casein which are in solution. The casein itself is insoluble unless you dissolve it, say in lime water; you could dissolve a little of it.

33767. Are there not matters present which can be thrown out chemically ?—To throw it out ?

33768. To throw out as much as possible, so that you would only have the sugar remaining ?—If you add any of the old precipitants, such as salts of alumina or iron, you will carry down the casein and you will get a clear effluent.

33769. I was not thinking of it from that point of view, but from the point of view of making a valuable food. Would gelatine throw it down ?—I would not like to say; I have not tried it, therefore I do not know.

33770. Some substance which would make a cattle food of it ?—I cannot say, because I have not tried anything. and I do not know of anyone who has.

33771. Obviously, if profit can be made of it, that is the right thing to do, is it not ?—Certainly, if you can make money out of your bye-products, that is the right thing to do; I quite agree with that.

33772. It appears to me the other problem is simply one of expense. It is perfectly certain to be purifiable by one of the ordinary processes, but whether it is the best thing to destroy it and throw it away, or to try and make money out of it, has yet to be determined ?—Of course what we recommend is to put it on the land if it can be managed.

33773. And to use it as a manure ?—And using it as a manure. We only recommend the use of the septic tank with these bacterial beds in those cases where land cannot be got or it is unsuitable, or where a nuisance might arise. For instance, land might take it in a dry season that would not take it in a wet. You might get pools of decomposing sewage, and then the smell might be a source of nuisance and give great trouble.

33774. Is steam used in an ordinary creamery ?—Yes. For instance, a large creamery will have a boiler 18 feet by 8 feet 6 inches.

33775. There must be a lot of waste heat there ?—They use the waste steam from the engine for heating the milk for separation, or it may be for pasteurising purposes, and finally for making hot water for cleaning purposes, so that out of the whole day's work the exhaust steam perhaps for a couple of hours is all that is wasted, or perhaps I should not say even a couple of hours. Then, of course, the boiler fire is banked, and there is very little coal consumption till the boiler is wanted next day; so that where the creameries are fitted with feed-water heaters and use the exhaust steam for heating the milk, there is very little waste steam, or very little waste heat.

33776. It is possible; the plant is there, so that you can get steam ?—We can get steam.

33777. We are not dealing with human food, we are dealing with cattle food ?—Yes, but it would not pay.

33778. Would it not be possible to evaporate such a substance in an open channel; not make the elaborate plant for boiling in a vacuum, but in the open, so as to make a stuff cattle would eat ? It might be a caramel, more or less, but still it would be a food that cattle would eat; that appears to me to be the solution ?—You know it is not an easy thing to evaporate, say, a ton of liquid in the open, especially in a humid climate.

33779. Not in shallow pans ?—Shallow pans; do you mean with natural or artificial heat ?

33780. I mean with the heat from the boiler. It would cost something, but would it not cost less than the value of substance recovered ?—I think it would cost more.

33781. You have a very high percentage of solids in these liquors ?—The highest we have got is 1,123 parts per 100,000.

33782. That is about 1 per cent., say ?—Yes.

33783. Is there no way of increasing that by methodical washing ?—That is by reducing the amount of water ?

33784. By reducing the amount of water ?—Well, that sample was actually taken from the creamery where the reduction of the amount of water going into the sewage is carried to the finest point. At the same time, in that particular sewage there is a good deal of milk sugar, because some whey from cheese-making was run into the sewage ; the farmers did not want the whey.

33785. (*Colonel Harding.*) The interest of this Commission and the inquiry we are making rests very much on the question of the pollution and the volume of the effluents which are discharged. You have told us that in one case the discharge might reach as high as 25,000 gallons per day ?—That is an exceptional case.

33786. That is quite exceptional ; I suppose 4,000 gallons would be an average ?—4,000 gallons would be a fair average from an ordinary creamery.

33787. Is this development of co-operation in butter-making one that has risen and that is growing ?—Well, the creamery movement in Ireland started somewhere about 1886, and it was taken up chiefly by proprietary people, I think, to the year 1889. Then the co-operative system was introduced by Canon Bagot and Sir Horace Plunkett, and the creamery system has gone ahead very rapidly, and it is going ahead more rapidly.

33788. So that there is a probability, therefore, that whatever nuisance arises from this discharge might become greater ?—From the number of creameries increasing, certainly.

33789. I take it from your answer that the export from Ireland of butter is steadily increasing ?—The official figures that I have given you here of our exports are what you might call the wholesale trade, and they fell for a year or two, but they are increasing again now ; but our trade by the passenger train or by the Parcel Post has increased enormously, and is tending to increase.

33790. Now, as to the objection arising from these discharges ; you, I think, told us that you believed there was no satisfactory evidence that cattle were directly injured by consuming water polluted with it ?—Not to my mind.

33791. Then what is the nature of the nuisance ; is it a bad smell, or is it a choking-up of streams by deposit ?—Well, bad smell from the pollution of the stream ; the fact that the water is absolutely spoiled for household or other purposes by this sewage if it is not purified to some extent and if the stream is a small one. Of course, if it runs into a big river, one finds generally it is clean a short distance below the outfall. That is where the stream is big enough to dilute it.

33792. Then the injury produced consists partly of a nuisance, a smell, and partly of the pollution of streams that can no longer be used for the purposes for which they were used before ?—Yes ; and that people state that their cattle suffer, but I have never seen it.

33793. Most of the cases of litigation have been for that definite purpose ?—Well, for all purposes, pollution and damage to cattle ; in some cases pollution only ; that the water is spoiled for household purposes ; in other cases, that the cattle had been damaged.

33794 Just a question or two in regard to the possible remedies. You say that precipitation by various substances has been tried and has failed. Now, by whom have these experiments been tried ? Have they been tried under the direction of the Department ?—No ; the Department was not in being when those experiments were tried.

33795. So far as your Department is concerned you know nothing of the effects of the addition of certain chemical substances ; for instance, lime to produce precipitation ?—The Department does not, but personally I actually did it myself, because I was in Ireland in the employ of a big private company, and under the Commissioner of National Education before the Department was formed, so that I personally have a knowledge of it, but the Department of Agriculture, which did not come into being till 1900, had no knowledge of it.

33796. But your Department did carry out certain experiments ?—Yes.

33797. Of which you tell us, in septic tanks ?—Yes, in the septic tanks.

33798. Were those carried out under your direction ?—Yes.

33799. The experiments that you made in precipitation, and which you say were unsuccessful ; to what extent did you carry them out ? what was the nature of the experiments that you made ?—We erected tanks, in which the sewage was collected ; we tried numerous precipitants : lime alone, lime and salts of alumina, and salts of iron ; in fact, the best precipitant was a salt of iron, which had been obtained from a man in Lancashire, who has written a book on sewage pollution, but I cannot think of his name at the present moment. The precipitant was something like the salts of iron used as a mordant by silk dyers.

33800. (*Mr. Kershaw.*) Mr. Wardle, I think ?—Yes ; it was Mr. Wardle. He sold a compound that, I think, with lime was the best clarifier we came across, and we tried nearly all that were in vogue at that time.

33801. (*Colonel Harding.*) What did you find as a result from these experiments ?—We found that the clear effluent decomposed, caused nearly as much nuisance as the unclarified sewage and that the daily removal of the sludge involved very much increased costs.

33802. But what was the effect on the settlement of suspended matter ?—It caused the suspended matter to settle down.

33803. It did settle down ?—Yes.

33804. And did it settle with great rapidity ?—It settled in a few hours, I think ; as far as I remember now it would be nearly 12 hours. We added the precipitants in the evening, after the sewage was collected, and the next morning the effluent was run off.

33805. The experiment was carried on by your Department, and apparently you seem to consider it was not conclusive ?—I do not know ; we are quite ready to adopt any suggestion which will give better results.

33806. Still, that was what you recommended, was it not ?—So far as we have got at present that is what we recommend.

33807. It seems to be the best ?—Yes.

33808. You have a tank capacity of 14 times ?—7 to 14, according to the sewage.

33809. Does not that lead to active putrefaction, and does not the effluent stink very badly when it comes out of the septic tank ?—It does, even after a couple of days in the tank you might say it smells very badly.

33810. But after 14 ?—After 14, coming out it has a smell, but we find if it is run quietly into a contact bed we can get rid of that smell without giving rise to a nuisance. I do not know exactly why ; I cannot give the reason myself except that perhaps the smell is disseminated more slowly, and then we found that if we added a very small quantity of chloride of lime—it would be a very small quantity—we could get rid of that odour.

33811. Do you not think it would be advisable to get the settlement of the suspended matter carried out as promptly as possible before putrefaction sets in ?—Well ; from my own experience of this sewage, it was of no advantage whatever.

33812. You mean that the effluent clarified was still very foul with dissolved impurities ?—It gave just as much trouble.

33813. Only would it not in that clarified condition be much easier to deal with upon contact beds or percolating filters ?—Than our effluent was from a septic tank six to ten days old.

33814. Than the crude effluent ?—On filters I grant you it would be better than the unclarified sewage, because the unclarified sewage would choke up any filter that we have come across.

33815. Because your suspended matter on a average is something like 250 per 100,000, is it not ?—Well, about 170 to 200 ; I give an average figure of one creamery here somewhere.

33816. Then no attempt has been made to purify on percolating filters the effluent that has been first precipitated ?—Well ; we have never tried a sewage clarified by precipitation on a percolating bed at all because we found that the labour and trouble involved in moving the sludge regularly was far more costly than building a septic tank

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that would hold say six to ten days' flow and that needed emptying only once in a year.

33817. Why did it need emptying only once in a year ?—Because most of the solid matter has decomposed, and it is just at the end of the year there are these 18 inches of sludge at the bottom and a foot at the top, and we simply run that into a sludge pit; it keeps down the cost from our point of view.

33818. And the suspended matter comes out of your septic tank after 14 days stay in it ?—I do not think I have any figures here because we did not worry very much over that at the time because we were not dealing really with the purification of the sewage; we were getting the creamery out of the difficulty. (*See* Table III.)

33819. I am afraid the impression on my mind is that serious experiments have really not been carried out hitherto for the solving of this difficulty ?—Well; I may say that other people have been working at this. Dr. Adeney and Mr. Kaye Parry of Dublin have been working at creamery sewage and they practically failed to purify it, and two or three other engineering firms and advisers or experts in the purification of sewage have failed, so the matter, so far as we are concerned, stands in this way, that we find that the septic tank treatment followed by either a bacterial contact or a percolating bed is the best, but we do not pose as sewage experts.

33820. Several matters which you have detailed to us may have obtained results in the one case which gave the effluent oxygen absorption in four hours of 12, and under other and improved conditions, the oxygen absorption of 5 ?—Yes.

33821. Well, that appears to be a very great improvement, of course, upon the crude liquor ?—Yes.

33822. Is it one firm that has adopted this, or several firms ?—Oh, no; at present there are 15 firms that have septic tanks, to our knowledge.

33823. On these lines ?—And these seven firms that have septic tanks followed by bacterial beds.

33824. Do these seven firms bring about results analagous to those you have mentioned of twelve and five ?—Some of them bring about better.

33825. Better than that ?—Yes.

33826. How much better ?—Because in one case they dilute the sewage a little. I can give you figures here now of a case where the septic tank holds 14 days' flow, I believe. The oxygen absorbed has been brought down to ·132; about ·1, you might say. (*See* Table III.)

33827. In 4 hours ?—In 4 hours, yes. This is a case where they had a small collecting tank, contact beds, and percolating beds. At first they ran the sewage through the system untreated in a septic tank; then they tried a process that has just been brought out, and it is on its trial. It has been brought out by a gentleman named Mr. Dickson, who runs the sewage into a tank; he adds ground rock phosphate and brewers' yeast. His idea is that the ground rock phosphate is rendered soluble, and that the effluent from the settlement tank is pure. These particular people tried that, and they gave it up as unsatisfactory. They then appealed to us, and we advised them to add this septic tank, and when the septic tank was added on to what they had got, that is to say to a small collecting tank, two contact beds and two percolating beds in parallel, the effluent from the septic tank is brought down to the figure I have mentioned; whereas before they could not get anything lower than, I think, it was 6 or 9.

33828. That was due not only to the septic tank, but to some dilution ?—They tried the dilution on the other method as well.

33829. Now, on the point of dilution, have you formed any opinion whether concentrated liquor, which you seem rather to recommend—— ?—Inasmuch as it costs less to put up the tanks.

33830. But have you formed any opinion as to whether that concentrated liquor is more or less difficult to deal with in percolating filters than a more dilute liquor ?—I do not think it is, because by the time it is run through the septic tanks, at the end of say six or ten days, there is very little matter in suspension—and we found no difficulty in dealing with that in a contact bed or a percolating bed, with Adams' distributors, and some other distributor, of which I forget the name; one of these revolving distributors deals with the effluent very well.

33831. One final question I will ask you. The farmers who have adopted the system of septic treatment followed by percolating or septic tanks, and have brought about results which you consider to be very nearly satisfactory; have they done it at a reasonable cost; at a cost which may be considered not too prohibitive to be universal ?—Some of them have, and some of them consider the cost very high. In some cases, septic tank treatment alone will perhaps get them out of the difficulty, I do not think it will meet your standard, mind you, but it will get them out of the local difficulty. A septic tank may consist of an excavation in stiff ground, covered with planking and 6 inches of earth. The contact bed has been made simply an excavation filled with limestone.

33832. The point, of course, is this; if it is possible to bring down this pollution to anything like two to three parts of oxygen absorption in 4 hours, would it be a reasonable thing for a local authority to call upon a creamery to carry out such a process ?—I think if the refuse were a nuisance, that the creamery should take some steps to avoid the nuisance.

33833. I am speaking, of course, if there is a nuisance ?—And in most cases, if the works and the methods are properly carried out, improvement can be effected. Whether it would be such as would meet the proposed standard laid down or suggested by you in the previous Report I could not say just at present, but I could get some analyses made later on and send them to you, if they would be of service.

33834. Nuisance only arises where there are discharges into a small stream; where there are large discharges into a big steam it is not necessary to do anything ?—If it were proved to me it was necessary, I would be glad to do something, but it has not been shown to me to be necessary.

33835. A large dilution does, in fact, remove the difficulty ?—We have discharges into very good fishing streams where there has been no trouble at all, because the stream was a large one. I may say that one of the difficulties we have to deal with in Ireland is this; these creameries are in country places, and it is a very difficult thing to get even the plans which are sent down carried out properly; and then it is also a very difficult thing to get the proper supervision exercised, because they all look on the sewage as a thing to be neglected, and in some cases it has been neglected, and plans which we have given to people have failed because they were neglected. As an example, we always state that the septic tank is to be watertight, but if the ground is stiff enough, and there is no danger from any sepage, it can be a covered excavation. In one case when they came to open the ground they found that half of it was bog and the other half a running sand. They covered the bottom half over the running sand with a thin layer of concrete, and left the other half uncovered, the side walls being made of 9 inch brickwork and ordinary mortar. Well, the sewage simply went under everything, and came up outside to create no end of a nuisance. As showing the difficulty of dealing with this sewage mechanically, I may say that, at another creamery, a large plant was put down under the advice of a well-known engineer, and with all modern devices. The last thing I saw of that, they were blowing it up with dynamite. That is actually the case; the plant worked so unsatisfactorily; the sewage choked the pipes, and the septic tank treatment was not long enough.

33836. There is one point that I had omitted; you gave us an instance, I think it was at Mitchellstown ?—Yes.

33837. Is that the Mitchellstown that someone told us we ought to remember ?—Yes; precisely.

33838. In that case a local authority complained that the discharge of this liquor into their sewers had injured the entire sewers ?—Yes.

33839. That was the allegation. I notice the case was dismissed, but what was alleged ?—The local authorities alleged that the addition of this sewage to the town sewage rendered the working of their percolating beds inoperative; choked them up.

33840. Then, in that case, was the volume of the discharge from the creameries much larger than the discharge of their actual sewage; was the quantity of effluent from the creameries larger than the amount of their domestic sewage ?—Oh, no; there was about 1,500 gallons from the creamery.

33841. And the domestic sewage would be much larger ?—The town has got a population of about 3,000. I think, speaking from memory; there would be the usual quantity of sewage.

33842. We may take it then, that in that case it was shown that no injury had been caused to the treatment of the domestic sewage ?—The case was dismissed; that is all I can say. Personally, I think it interfered slightly with the working of their tanks.

33843. (*Mr. Tatton.*) With regard to your septic tank treatment, am I right in understanding, that you only had one septic tank—you had not a pair; there was no division; it was just one flow through a septic tank ?—A long narrow tank was the first; our latest is to have it in three side by side, and then we find that the first section is nearly the only one that wants sludge taken out of it at the end of the year; that there is very little collected in the second and third divisions. At the same time there is some change goes on in the sewage while passing through those divisions, which seems to make it more suitable for treatment in the contact or over the bacterial beds. What that change is I cannot just say.

33844. From those tanks it went on to your contact beds ?—Yes, it went into a contact bed, or we tried it over the percolating bed.

33845. Did the contact bed survive; during the whole of the 12 months had you to clean out that contact bed ?—We tried coke and we had to empty them, but when we used gravel or lime-stone we have not had to empty them out, except at the end of the year when they were riddled. I do not say that a more effective purification might not have been brought about if they had been cleaned, but we wanted to keep the amount of labour down to the minimum.

33846. But the coke failed, because the coke broke down ?—The coke broke down, and clinker breaks down. We tried clinker, which was a most difficult thing for us to get; in fact we had to import some to get good hard clinker, and it broke down.

33847. But you do not find that your lime-stone gets blocked with the suspended matter coming from the septic tank ?—No, it gradually gets less, being dissolved.

33848. (*Chairman.*) It dissolves up ?—It dissolves up and it neutralises the acidity of the sewage. We started with coarse lime-stone, which is ordinary road-metal, but we now recommend what they call the lime-stone chippings, that is the refuse from a stone-breaker, such as is often used for the top dressing of a road when tar is put down; the little chippings which vary from half an inch to an inch in size.

33849. (*Mr. Tatton.*) Do you clean out your contact bed when you clean out the septic tank ?—We recommend them to; I do not always say they do it.

33850. You spoke of making a change in the stream after these works were put down ?—Yes.

33851. How long did the stream take to purify itself ? Well, I could not just tell you that offhand, but the next season, with the changes, we found that there was this good effect. I may say that the stream in this particular case was perfectly white for a mile and a half, almost till it got to the river, which would be perhaps two or three miles. When we left it you could not see where the effluent went in, and there were none of those great algal growths that you usually find in sewage streams. We found none at all. You see the dilution was sufficient to prevent the growth with the oxygen absorption in four hours that you see given here; it varied from 3·8 to 6·6.

33852. What dilution would you have in dry weather, in the summer ?—I just remember working that out; I do not think I have got the figures here.

33853. Could you tell us roughly ?—Well, if I remember rightly, it was something between 300 and 400.

33854. As much as that ?—I am not certain, but I could add that figure.*

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33855. Anyway, it is over 100 ?—Oh, yes, it was over 100. Of course, we could increase that by running the effluent slower out of the contact bed; I mean we could increase the dilution. In this particular case I may say, that owing to the business having increased, there is far more sewage to deal with, and they have not increased the plant as much as they ought to have done, and there are signs now of this growth along the stream for about 450 yards, but it has not been productive so far of their putting down additional plant.

33856. (*Chairman.*) Is the stream polluted; are there people living on the bank ?—Yes there are people living on the bank drawing water for household purposes, and they complained before the works were put down; in fact I do not wonder that they did complain; they had good reason for it, the thing was an abominable nuisance and the water was destroyed for all household purposes, which was what it was generally drawn for. There are no complaints now.

33857. (*Mr. Willis.*) Is that the way that most of your villages get their water in Ireland ?—No, I do not say villages; just different houses, labourers' cottages, farms. I do not say they use it for drinking at all, just for ordinary household purposes.

33858. Does your Department administer the Rivers Pollution Prevention Act, or is it the Local Government Board ?—I think it is the Local Government Board that administers that; we have nothing to do with it.

33859. Do you happen to know whether county councils take any active steps to enforce that Act in Ireland; have you heard of any prosecutions undertaken by the county council against manufacturers ?—No; I cannot call to mind any. No, the trouble generally arises through a private individual, or in a few odd cases, I think the Fishery Conservators have complained about pollution.

33860. So far as you know, they do not use the Rivers Pollution Prevention Act ?—Not that I am aware of.

33861. (*Chairman.*) Have you personally anything to do with this ? You are Inspector of Dairying, but does that involve any control over the refuse ?—Not obligatory.

33862. (*Mr. Willis.*) You are really interested from the trade point of view ?—From the technical point of view.

33863. That is the interest of agriculture ?—Yes.

33864. (*Chairman.*) I suppose, if the refuse could be made valuable, you would be interested ?—We certainly would take it up at once and we have always examined any cases that have been put forward. For instance, this manure case, where the man is making a valuable fertiliser, as he stated, by putting this ground rock phosphate and the yeast into the sewage; we examined that, but we could not recommend it, and unfortunately I have been ill, or I would have been able to tell you something probably about this new method he has brought out now of aerating the sewage by centrifugal force. That is he will run it, as far as I understand, into a machine something like a sugar drying machine, and then the fine streams of sewage impinge on plates and are aerated. Whether it is a success or not, I do not know, but it might be of interest to you to know that there is such a process.

33865. (*Mr. Willis.*) You have only been interested in those experiments from the point of view of avoiding trouble with private individuals ?—And Fishery Conservators.

33866. Therefore, you take no trouble to see whether the effluent that you ultimately get is a non-putrescible effluent; it was an effluent that was sufficient to avoid the trouble ?—Yes, to avoid the trouble.

33867. That is all you went for ?—Yes; whether we had got a non-putrescible effluent or not did not concern us.

33868. In the case you mentioned, where there was very large dilution ?—Where there was fairly large dilution, and where they had this complete plant.

33869. But these experiments which you have carried out yourself did not give you a non-putrescible effluent, did they ?—Not quite, but they were sufficient to get the creamery out of trouble.

33870. Do you, as a Department, advise that if they can reduce down to that, that will be satisfactory ?—No, we do not say that.

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* Note.—The maximum amount of effluent at this time was about 4,000 gallons in three to four hours. The flow of the stream varied from 12,000 to 400,000 gallons per hour.

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33871. You avoid saying that ?—Because unfortunately there is no standard, and we could not make a statement of that sort, because it would immediately be brought up against us, and perhaps an action taken. We simply say, that our experience is, that if they adopt this septic tank treatment, and add sufficient bacterial beds, they will get over the difficulty and we refer them to the places which are at work, and they can go and see them.

33872. I rather gather from what you said that you send out plans actually to these people ?—We send a rough sketch plan to send to their architects, but we do not act as architects or Clerks of Works.

33873. And in that sketch plan you indicate particular sizes of tanks and contact beds ?—Yes, based on the particulars they supply to us and inspection of the premises.

33874. Based on the flow they give ?—Yes.

33875. And in determining what suggestion you will make, what effluent do you aim at producing ?—Well, it is a plan that can be added to so readily that we will tell them first to put down a septic tank. If the effluent from that is sufficient to get them out of the trouble, you let it stop there.

33876. You say it is necessary to do that first ?—Add the contact bed, if that is not sufficient they can add the percolating bed; it can all be added fortunately, so they can try first a septic tank alone, a septic tank and a contact bed, and finally a septic tank, a contact bed and a percolating bed. A percolating bed on the effluent direct from the septic tank, as I have said in my note, caused a nuisance.

33877. Then, of course, you are only careful to see that they put these various things at such levels that they can add other things afterwards ?—That they can add; we do not want to run them into unnecessary expense.

33878. In regard to Mitchellstown, I rather gather that you felt perhaps that the admixture of this creamery refuse did make the sewage rather difficult to deal with ?—Well, I found in creamery work, the creamery sewage clogged up the contact bed or the percolating bed, unless it had good septic tank treatment, and their septic tank was only for the 24 hours' flow; under those circumstances, in my mind, it might have interfered with it.

33879. That is the impression ?—I do not say it did, but I saw the place and I was actually subpœnaed as a witness, but had not to give evidence in this particular case.

33880. In the case you told us, the population was about 3,000 you thought; you did not remember exactly ?—It might be 5,000, but it is somewhere about that.

33881. You said the flow of sewage from that population was about normal ?—I suppose it would be.

33882. What do you call normal in Ireland—20 gallons a day ?—No, I think it is taken as higher—35 or 36.

33883. At 20 gallons a day, had you had 3,000 people, that is 60,000 gallons a day ?—Yes.

33884. I think you said the discharge from this creamery was about 1,500 ?—About 1,500 at the height of the season. One of the difficulties in regard to the septic tanks is this; the big flow of sewage is in the summer months.

33885. That I know; if you will excuse me one moment I do not want to go off on that. We will assume the population is 3,000 and it is 20 gallons per head, that is 60,000 gallons of sewage a day, and the maximum discharge from this creamery is about 1,500 gallons ?—About that; it might be up to 2,000.

33886. That is the maximum ?—Yes; it might fall in the winter to probably 1,000.

33887. And your impression was that that 1,500 or 2,000 gallons, mixing with the 60,000 gallons made the 60,000 gallons really seriously more difficult to treat ?—That was just my own impression.

33888. This Commission has recommended that normally the right thing to do with trade refuse is to put it into sewers ?—Yes.

33889. They stated that the admixture of trade refuse may make the sewage sometimes a little more difficult to treat, but that they were not aware of cases where it has made it impossible or really so difficult as to be impracticable to treat the mixture, and what was in my mind was this, whether you have got enough experience in Ireland to enable you to say to the Commission you would not advise that in the case of creamery refuse. The only case you mention is Mitchellstown, and there you said that this small amount really seriously increased that difficulty ?—With that plant; with the plant that they had; I do not say that the difficulty could not have been got over; in fact I think it could with very little trouble.

33890. Let me put this general question to you; do you consider in Ireland where there are sewers available, that creamery refuse should be allowed to be discharged into these sewers ?—I do.

33891. And would you make a charge on the creamery for taking that refuse ?—No, I would not.

33892. You would let it go in free ?—I would let it go in free.

33893. I rather gather, after the answers you gave to Colonel Harding, that you yourself consider that this question of purifying this creamery refuse has not really been very fully worked out ?—I would not say that improvements cannot be effected in it, but as far as I can see we are doing the best we can with it at present.

33894. That is not quite an answer to my question. Do you, as a scientific man, think further work is needed on this question ?—I would like to see further work on the question, but at the back of my mind I am afraid the further work will not bring about any change in the methods at present adopted. That is just the way it is in my mind. I would like to see further work done, and I would like to see, if it were possible, and I think it has been done in some other cases, the Commission take up the case of one creamery and investigate it; I believe that has been done in the case of some other trade wastes.

33895. But in Ireland your Department has itself started and carried out some experiments ?—We had to because there was no one else to do it.

33896. You have done some ?—Yes.

33897. Why should you not do more if the question is not dealt with adequately ?—I think I might say the Department would be quite willing to co-operate with you in carrying out any further experiment you would like.

33898. This Commission is drawing to a close, and it will have to make some recommendation about various things. It occurred to me whether it should say in regard to this creamery refuse that we have heard from you and others of the experiments that have been made, but that in the opinion of the Commission the things has not been fully worked out, and further experiments are desirable ?—Well, I would like to see some further experiments on it, but from our point of view, that is to get the creamery out of its difficulty, we think we are working on the cheapest lines with the methods suggested.

33899. You look at it rather like the manufacturer ordinarily looks at it; do the least you can ?—That is exactly our point of view. At the same time, the Department, I am perfectly certain, would not like to inflict a nuisance or cause pollution.

33900. We know, do we not, that merely passing this stuff through a septic tank is not going to purify it, and yet you as a Department advise farmers to start with that ?—But what is the standard ? We have no standard in Ireland; we have the standard that you suggested, but that is a suggestion at present.

33901. There can be no possible doubt that passing this creamery refuse through a septic tank, even for 14 days, will not give you a non-putrescible effluent ?—It does not give you a non-putrescible effluent.

33902. Not the effluents that ought to go into a river, having regard to the Rivers Pollution Prevention Act ?—Well; if you take the Rivers Pollution Prevention Act, you cannot run anything into the river.

33903. Not unless it is purified and rendered harmless ?—Where is that standard of purification; there is no standard ?

33904. At any rate, most people seem to assume that it should be something that will not putrefy, that is fairly well recognised ?—We have cases of something that will

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not putrefy being put into the streams, and yet we have law troubles. We would like the matter settled so that we would have a standard to work to, and know where we are.

33905. Excuse me; I do not want to take up a lot of your time; you have not tried passing the effluents, after chemical precipitation, through a filter?—No; and our reason for not doing it is, that where we had chemical precipitation, the labour and trouble required in getting rid of the sludge rendered the process useless for the country creamery, where it would get very little supervision.

33906. (*Colonel Harding.*) I am very unwilling to interrupt Mr. Willis, but I should like to ask whether any experiments were made in unassisted settlement?—Unassisted settlement?

33907. I mean, without precipitating materials; natural settlement?—Well; we did, in this way, that we tried to filter the sewage.

33908. Never mind the filters, but in regard to settlement, did you try the experiments which would show whether sewage quiescent in a tank say for a couple of hours would deposit any large part of its suspended matter?—In a couple of hours it would not.

33909. (*Chairman*) In 12 hours, you told me, it does?—In 12 hours it does deposit.

33910 (*Colonel Harding.*) By simple settlement?—By simple settlement. I understand with the sewage in a bottle you would get settlement.

33911. (*Mr. Willis*). Did you try running on simply settled sewage?—A fresh day's.

33912. Settle it for 12 hours; then you run it on to a filter?—That was the treatment that was carried out in this place which they blew up. It was exactly what I take as a normal town sewage plant; 24 hours' settlement; then contact beds.

33913. Did you find there, that the contact beds choked very rapidly?—I did not see them till they were being destroyed; they told me they did, and they told me the valves choked, and that the whole thing did not work at all and could not be got to work satisfactorily.

33914. With your septic tank large enough to take 4 or 5 days' flow, how often had you to clean your filter beds?—Well, as I told someone, once a year. I think I explained that we tried to get rid of the trouble by emptying this sludge out once a year, because it is not exactly a sweet piece of work, and we tried to arrange so that it would be emptied once in the year when the work was slack at the creamery; that would be in the winter months.

33915. How was it you got this very good effluent at a place; was it simply by diluting it?—It is partly the dilution, the septic tank and contact and percolating beds.

33916. On p. 10, the last page but one?—No; I think I gave you that figure from a file I have here; that is where it was. (*See* Table III,)

33917. You got below one oxygen absorbed?—Yes.

33918. How did you do that; I did not quite follow you? First of all you had a septic tank, taking how many days' flow?—We calculated that it would take a 10 days' flow; it will hold perhaps 14 in winter; it might run down to 7 in the height of summer.

33919. After going through these tanks, where did it go?—It runs into a little collecting tank for feeding the automatic device.

33920. On to the contact bed?—On to the contact bed.

33921. Only one?—Only one.

33922. And the effluent issuing from that contact bed?—Over a percolating bed.

33923. Then over a percolating bed?—Then into the stream.

33924. What was the effluent as it came from the contact bed; in that case what was the oxygen absorbed figure?—There were two contact beds side by side and used alternately, one filled with limestone and one with clinker. From the limestone bed, 3·95, and from the clinker bed, 3·95; they were practically the same.

33925. And what was the oxygen absorbed; of the liquor as it went on to these contact beds?—On to the limestone bed, 4·28; on to the clinker bed, 4·28; they were practically the same liquor going on.

33926. And the effluent, after going through the percolating filter, was what?—After going through the percolating filter, in one case ·132, and in the other case ·099. (*See* Table III.)

33927. How long has that plant been going, I mean, some years?—Oh, no; in this particular case they had had the percolating bed, the contact bed, and the collecting filter put down, and they did not work; they were in trouble, they wrote to the Department. About six months' with the septic tank, I should say, roughly.

33928. Do you happen to know the original figure of the creamery refuse; what was the strength of that?—No; because we did not keep any figures. They have got a man there that can do the oxygen absorption now. (*See* Tables I. and II.)

33929. Your average figure for creamery refuse; oxygen absorbed, is about?—180 in the undiluted condition.

33930. Do you imagine that the passage through that septic tank reduced it from 180 down to 4·28?—I do not say that this was 180, as matter of fact; I can give you some of the figures of this particular place.

33931. Supposing it was 100?—It varied from 127 down to as low as 39. (*See* Tables I. and II.)

33932. But I take it that these figures that you have given us for the effluents are fairly average sort of figures?—Yes; the average for the Ballyrashane Creamery is 180, and the other figures are from creameries, with the exception of one——

33933. I think we are rather getting away from the point. What I really want to know is, given that this was a fairly normal creamery sewage refuse, we may assume that it is reduced by that septic tank, from whatever figure you like to put it at, 100 or 150, down to 4·28 from the septic tank alone. Do you think that that is reliable?—I think so, because our own man took these samples, and spent the whole day there.

33934. (*Mr. Tatton.*) From the septic tank alone or the septic tank and contact bed?—The septic tank alone.

33935. (*Mr. Willis.*) What comes out of the septic tank is 4·28?—Yes. The case of the creamery whose sewage is given as the fourth in the Table there; the one with the asterisk.

33936. (*Chairman.*) "Total solids, 315"?—Yes; but with 14·15 oxygen absorption. That is a very low figure for that particular case and determined with $\frac{N}{80}$ Permanganate, because here the regular daily work of this place, according to the figures taken by their own man, of the raw sewage; well, it has been as low as 27 with him, and been as high as 87 on that particular sheet. That must have been pretty well diluted in that case with the condensing water.

33937. (*Mr. Willis.*) If the normal creamery refuse is 160, or something like that, and in this instance you were experimenting with something which was only 14, obviously it is a very exceptional case, and you cannot draw general inferences from it?—I am not asking you to draw general conclusions from that, but the samples were all drawn on the same day, so the effluent from the septic tank going into the bacterial bed on that day would not be the effluent from that particular sewage, because that would not come out till perhaps a week or ten days later, you see. If it would be of any assistance, I can give you a table of the rough figures—I will not say they are absolutely accurate, because they are kept by a man who has simply been trained to do the oxygen absorption mechanically and are comparative.

33938. I was only asking that in order to see what weight we could attach to this particular experiment?—Yes; but in all cases it is all under one It nearly always comes under one at this particular creamery; one part per 100,000.

33939. Do they employ many hands at these creameries? Take a creamery with about 5,000 gallons of milk a day; how many hands would they employ there? That, I think you say, is a normal size?—Well; it is a bit on the high side; we will take 3,000, say.

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33940. 3,000 ?—There would be five to seven; that is at the height of the season.

33941. You gave us some figures as to the increase in the butter trade, but you said a great deal was now being sent by Parcel Post; is there any record of the amount sent that way ?—You cannot check it. And fast passenger trains; that is at the parcels rate. A lot of the butter and other agricultural produce is run in as parcels. You see just a parcel; it is not classified, so that there is a good deal more butter going over than is given here.

33942. (*Chairman.*) Would it be possible for you to send some samples of the septic tank liquid to Dr. McGowan ?—Yes; I could take this particular place and get samples each day of the septic tank, so that you could see the progress of the purification from the contact beds and from the percolating beds. I could easily arrange for that to be done. The Company gave me permission to take them before, and I do not see any reason why they would refuse now.

33943. Would you also send me a sample of the crude liquor as well ?—There would be rather a difficulty in sampling that.

33944. (*Dr. McGowan.*) You would have to take average samples over the same period ?—I could get samples from the septic tank. The flow is pretty regular because there is a valve on the outlet, and the flow is kept regular, but with the sewage there are inclined to be rushes, and it is not an easy thing to sample.

33945. (*Chairman.*) I should have thought the uniform working of a creamery would have given you a very constant liquid ?—No. The washing from the butter comes down every hour, we will say. Every time a churn is drawn there is a rush of the sewage then. We can take samples by dipping, and we tried to proportion these to the flow, but it is not just easy to do it. I have here some figures which I have not given you; where a tank sample of the raw creamery sewage does run into a tank and mix. We know it is a true sample of the day's flow. If you would care to have those, the oxygen absorption in four hours was 140, the free ammonia one, and the albumenoid ammonia eight parts per 100,000, and the solids in suspension, 142; total solids, 521. That was a tank sample only taken the other day. I just found that these people had a tank that they collected the sewage in, and thought it would be useful to have another sample.

33946. Would there be any advantage in giving samples from the various sections of the septic tank ?—It is just as you like; it might be of service from the point of view of settling this question of over-septicising. I was personally told by a sewage expert that we were over-septicising; I told him to see our tanks; he saw them, and he worked on this other plan and it has simply failed. When the problem originally arose, I may say I personally interviewed a number of chemists at sewage works and so on, and the sewage was such a difficult one, they practically had no experience of dealing with such a sewage, and we had to then simply evolve our own method.

33947. (*Dr. McGowan.*) There was a question that Sir William Power was anxious to have put. We see what difference there was between the liquor which had remained three days, say, in a septic tank, and the liquor which had remained ten or twelve. Had you gone into that; had you made any experiments to see what difference there was ?—We have some figures in this particular case, and simply the oxygen absorption; we found that it was reduced. I think I could give you some figures here. I would have to add them too. In one case, I will take just one day, leaving the first section of the septic tank, the oxygen absorption was 8·32, second section 5·98. Now, the third section, which was going on to the beds was 5·63 on that particular day. But I can summarise these figures if you would like them, and then I can send you samples from this particular place. It may be that the change is not exactly in the oxygen absorption, but perhaps some chemical and physical change which I do not know and cannot just say what it is, but I think there is some change takes place then, though the oxygen absorption figure remains the same, the liquid looks better; it does not seem to be so viscous. (*See* Tables II. and III.)

33948. (*Chairman.*) Just one question, which may seem rather absurd, but I am still considering the possibility of utilising those liquors. Do they come over a great distance to this creamery as a rule ?—They might come one or four miles.

33949. The cattle have got to drink water; they drink ordinary water ?—I presume so.

33950. Would it be conceivably possible to return this stuff, so that the cattle instead of drinking water might drink this ?—Well, I am afraid you would have trouble, because it would mean that the man would have to provide extra milkcans.

33951. He might have the returned empties ?—The separated milk is in the empty. He brings his milk, and gets 85 per cent. of separated milk, and perhaps five per cent. of buttermilk. He would have to provide extra cans for this sewage. I do not really think that is a practical thing.

33952. We are very much obliged to you, Mr. Wilson ?—There is just this point which I would like to emphasize. We have great difficulty in getting the man to attend to plant for the purifying of sewage, and in devising any method we want to make it automatic, as simple as possible, and reasonable as regards costs of installation and running.

Mr. Walter Thorp, B.Sc. (London), B.Sc. (Leeds), F.I.C., F.C.S., called in; and Examined.

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33953. (*Chairman.*) I think you are a Fellow of the Institute of Chemistry and of the Chemical Society ?—I am.

33954. You were settled at Limerick for a long time ?—Yes, I was.

33955. You are now in Dublin ?—I am now in Dublin.

STATEMENT OF EVIDENCE.

Dairy waste has given rise to serious complaints of nuisance, and also to legal disputes, in many parts of Ireland, where creameries have been established without due regard to drainage. In the early days of the creamery movement the site of a creamery was often determined by its proximity to cross-roads or to the fact of a cheap bit of land being available. Old mills formerly worked by water-power, but derelict at the commencement of the creamery movement twenty-five years ago, were in some cases adapted to the work of a creamery. Such a situation on the bank of a good-sized stream or river is ideal when we are considering drainage only, because the waste from a creamery appears to be innocuous when it mixes at once with a comparatively large volume of water. It is when creamery waste is discharged into a ditch with only a slight fall that trouble arises, on account of the excessive quantity of suspended solids. These solids are deposited at the bottom and sides of the ditch, and cause a stench in hot summer weather. It is during the months of June, July and August that creamery work in Ireland is at its maximum.

The bulk and strength of sewage from a creamery vary very greatly, not only with what we call the size of the creamery (as measured by the number of gallons of milk treated daily), but with the method of disposal of the sewage. If the drainage is defective the sewage is made as weak as possible by mixing with the water from the coolers. I have, however, met cases where the drainage is defective and the cooling water so scarce that it has to be used over and over again. If the drainage is good, and the cooling water plentiful, the dairy waste and the cooling water are usually allowed to flow together over the concrete floor of the drain.

The amount of actual sewage at a large creamery is not excessive. Putting aside for the moment the question of the after treatment of the dairy waste, the actual bulk of it need not exceed the volume of the milk received at the creamery, and may often be less. For instance, at a very large creamery in the south of Ireland, with which I have been familiar for the past twenty years, where the sewage has to be pumped a considerable distance to the irrigation fields, the maximum amount of sewage does not exceed 4,000 gallons per day, whereas the milk supply goes up to 6,000 gallons per day in June. Six thousand gallons of milk would yield 600 gallons of cream. After churning this, the buttermilk is drawn off, and returned to the milk suppliers. The washings from the butter in the churn are the chief source of the creamery waste, and the rinsings of the cream vats, the pumps, and the milk heater all contribute. The amount of waste due to the scalding and cleansing of the machinery and utensils is small compared with that previously mentioned.

I give as the result of a strong dairy sewage, where the bulk has been kept as low as is conveniently possible, the following results in parts per 100,000:—

	Parts.
Total solids	620
Suspended solids	235
Dissolved solids	385
Ash in dissolved solids	96
Ash in suspended solids	16·6
Total ash	112·6
Dissolved organic matter	289
Suspended organic matter	218·4
Total organic matter	507·4
Nitrogen in suspended matter	26·32
Nitrogen in soluble matter	12·40
Total Nitrogen	38·72
Total Chlorine in solution	19·25
Equal to sodium chloride	31·9

It is commonly said that creamery sewage is injurious to cattle, but in 20 years' experience amongst Irish creameries I must admit that I have never come across any definite evidence to that effect which I could regard as conclusive. There is evidence to show that cattle are fond of drinking water which is polluted by creamery sewage. At the same time, there have been many cases where negligent management has been responsible for a serious nuisance, and also for deterioration of the products of the creamery. If the dairy waste can be discharged into a stream with a fairly rapid current there is nothing to cause serious injury. The greater portion of the sewage consists of the washings from the butter, and this contains casein, lactalbumin, milk sugar, and lactic acid. At the time of discharge there is no putrefaction. The liquid is slightly acid. The bacterial examination of the washings when drawn from the churn would show at least 90 to 95 per cent. of lactic bacteria.

Where the creamery cannot discharge its sewage into a suitable stream I am of opinion that the most satisfactory method of dealing with the sewage is by the irrigation of land. The amount of land required for 1,000 gallons of milk daily I should put at a minimum of one acre, preferably two acres. With the former proportion a good deal of supervision would be necessary. At Ardagh the 4,000 gallons of sewage is irrigated over a field of two statute acres during the summer months, and the effluent is satisfactory, but at the sewage outfall the liquid is made to flow through a bank of peat, which stops most of the suspended solids. In the spring and autumn a larger field of thirteen acres is used for irrigation. The larger field is used for grazing purposes; the smaller field cannot be used for any agricultural purpose, though the peat used for the filtration of the sewage is considered of some value as a manure by the neighbouring farmers.

33956. You have had a great deal of experience in agriculture ?—I have been interested in creameries for the last twenty years, and my first acquaintance with the question of dairy waste was the difficulty that Mr. Wilson had at Knocklong.

33957. Is that long ago ?—In 1893 or 1894.

33958. I did not know that these difficulties had been going on so long. I did not know that the trouble had arisen twenty years ago ?—There was a good deal of prejudice against proprietary creameries when the co-operative creameries started, and I think a great deal of the trouble was caused by an amount of jealousy on the part of certain people. The trouble at Knocklong in my opinion was purely a local question, a question of local feeling.

33959. Are the people who say they are injured ever farmers who supply the milk ?—Well; it is generally a case of a man who has got some grievance against the creamery or against some particular creamery manager, and if he finds the dairy waste flowing into a stream which passes through his land, and he happens to have a cow die from any cause whatever, he makes a complaint.

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33960. You mention, in your *Precis*, of the trouble arising from the solids being deposited in a ditch ?—Yes.

33961. And that is common, I presume ?—It is common in many of the older creameries. Of course, as to the creameries which have been established within the last few years, they generally consult the Department of Agriculture, who very strongly advise them, wherever possible, to get near a good sized stream, if there is one anywhere available.

33962. So that the difficulty is curing itself by the fact of new creameries being built in suitable places ?—Yes.

33963. Do you think there is any possibility of making use of this material for food purposes ?—I am afraid not. I am afraid the creamery managers would not attend to the matter soon enough, and even when the dairy waste is a day old it is objectionable.

33964. Disagreeable ?—Yes, and I think the cost would be prohibitive. I have roughly worked out what I think would be the cost of treating a sewage of about 4,000 gallons a day, and I make out that it would cost about 25s. a day.

33965. That is including the labour and everything ?—That is including the labour and everything.

33966. You mean, by evaporating ?—By evaporating.

33967. Would the evaporated stuff have any value ?—It would; yes. I have given you some figures of analyses of a typical creamery sewage, and I make out the solid matter there would be about 240 lbs. per day; there would be about 10 lbs. of nitrogen in that.

33968. Would it be difficult to make cattle food from that. I presume alone it would be; cattle will not eat animal matter of that kind, but pigs would, of course; but would it be possible to mix it with grain, or with some cereal product to make cattle eat it ?—I think you would have a disagreeable product. I find on evaporating samples of dairy waste in ordinary flat dishes you do not get a nice product at all.

33969. It has a disagreeable smell ?—Well; it is acid.

33970. You give some analyses; you say you have no knowledge of its being injurious to cattle ?—No; I consider that a case of injury to cattle has never been really proved. Certainly the cattle do drink the creamery sewage whenever they get an opportunity.

33971. They like it ?—They like it, and I have seen cattle grazing on an irrigation field, and they were perfectly at liberty to drink out of the ditches whenever they wanted to, and I never saw cattle in finer condition.

33972. In some respects this liquid is analogous to pot-still refuse. As far as it is very acid, it serves as a food for cattle, but, of course, that is a different matter. Then you speak of the amount of land which is necessary to dispose of such refuse ?—Yes.

33973. You think for a couple of thousand gallons, one to two acres would be sufficient; have you experience of that ?—Well; I have had before me the case of a creamery; one of the oldest established in the country, and one of the most successful, the Ardagh Co-operative Society, and they have certainly treated their sewage in a very satisfactory manner, and in the summer months, June, July, August and September, they use a field of two statute acres, and they get a very satisfactory result. In the autumn and winter, from the 1st October to the middle of May, they use a much larger field. The quantity of sewage during those months is smaller; the evaporation is much less, and they want to give the other field an opportunity of recovering itself.

33974. Do the fields belong to themselves ?—Yes; I think so.

33975. There would be no objection to putting it on; it does not spoil the grass in any way ?—With regard to the small field, it does; they get a very coarse growth which is totally unfit for fodder, but in the case of the larger field they get a very rich growth of rather coarse grasses.

33976. Has it to be carried far ?—Well, they pump the sewage; they have a very large tank, and they pump it with a centrifugal pump a distance of about

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three-quarters of a mile. They have obtained permission to lay pipes along the public road.

33977. How do they distribute it on the fields ?—They distribute it by means of open drains. In the large field they divert the sewage from time to time, using a portion of the field at a time. In the case of the smaller field they let the sewage run first through a bank of fine peat, and then they distribute it as evenly as they possibly can over the field, and let it flow. There is a slight slope down the field. I have a map here. You can see from the map the way in which the drainage is disposed of.

33978. These districts where these creameries are are not populous as a rule, I suppose ?—Oh, no.

33979. There is plenty of chance of getting land cheap ?—No, not cheap ; land is not cheap in Ireland if it is good, but there is always an opportunity of obtaining land, and it is often a matter of arrangement with these co-operative creameries. One of the Committee men will lease portions of his own land for a certain sum.

33980. Does he consider that the land gets any benefit by this treatment ?—Yes. Of course, opinions differ ; if a man has got a grievance he will say the creamery sewage will ruin the land, but you always find farmers who are very anxious to get the creamery sewage for irrigation purposes.

33981. Next to food, the best way of disposing of it is as manure ?—Yes.

33982. (*Colonel Harding.*) You say the farmers are glad to have it for irrigation purposes.—They have it only at certain times and seasons ; not continuously ?—Well, of course, if they only use the field for grazing.

33983. But do you think that two acres for a creamery turning out 1,000 gallons daily could be used continuously year after year without its becoming sewage-sick ?—Two acres for 1,000 gallons ?

33984. Well ; that is the proportion that you suggest ?—Yes ; I think so.

33985. Continuously for years ?—I think so ; it has been done.

33986. But it could not be used for agricultural purposes ?—It could not be used for anything except grazing.

33987. Could it be used for grazing ?—Yes ; they do use it for grazing.

33988. It would not make the land absolutely useless ; it would not turn the land simply into a filter ?—No ; not that quantity. A small field of two acres at Ardagh can deal with 4,000 gallons a day, but they cannot use the land ; there is too much there. In the case of the small field at Ardagh, the two acres for the 4,000 gallons a day of strong sewage, they cannot use the land for anything else ; that is too much.

33989. But you say that in that case, by passing it through a sort of peat filter it does leave behind a great part of its suspended matter ?—Yes.

33990. In that case it produces liquor which you can deal with on the land ?—Yes.

33991. Does not that really point to the necessity, in connection with this kind of effluent, as far as possible of getting a sedimentation precedent to land treatment, or artificial filtration ?—It would be better, certainly, but there is great difficulty with regard to this creamery sewage, because it contains not only casein which is precipitated at the time you get the fresh sewage, but it also contains a considerable proportion of lactalbumen, which is soluble and is only precipitated very slightly. I have considered methods of getting over this, and I think it would be possible—I have not tried it on a large scale, but I think it would be possible—to get rid of most of the soluble albumen if the dairy waste were kept for 24 hours until it were thoroughly sour, and then the whole of the waste were boiled ; the heat then would precipitate the whole of the lactalbumen. The lactalbumen is not easily precipitated by boiling in a neutral solution, but it is readily precipitated in an acid solution.

33992. Would it not be possible to carry out small laboratory experiments on those lines ?—It would. I know that this is true, as soon as you get the liquid sufficiently acid you get down practically the bulk of the lactalbumen by boiling.

33993. (*Chairman.*) The casein is already precipitated ; is it not ?—The casein is already precipitated in the fresh sewage.

33994. So that practically there would be nothing but milk sugar left ?—Yes ; after boiling the acid solution.

33995. (*Mr. Tatton.*) You spoke of there being 4,000 gallons of the sewage out of 6,000 gallons of milk. What does the balance represent between what is received at the creamery and what goes away as sewage ?—You see, a farmer brings in his milk ; he leaves say 100 gallons of milk ; he takes back 85 gallons of separated milk and also about five per cent. of buttermilk, and he leaves behind him about 10 gallons of cream. Well, that cream is churned, and the principal portion of the dairy waste comes from the churn after the buttermilk has been drawn off. The buttermilk is drawn off first and then the butter has to be washed, and the first washing of the butter is the principal source of the dairy waste.

33996. The washing water, of course, adds considerably to the dairy waste ?—Yes, to the bulk.

33997. What does the farmer do with the buttermilk that he takes away ?—He chiefly uses it for feeding pigs. The separated milk is mainly used for feeding calves and pigs.

33998. Is the pollution from the cheese-making worse than the pollution from the butter ?—Worse, I should say, unless you can induce the farmers to take away the whey, and farmers as a rule have a very poor opinion of the value of the whey.

33999. What is whey used for ?—They can only use it for feeding pigs.

34000. (*Mr. Willis.*) What kind of land do you regard as most suitable for the treatment of this creamery refuse ?—Light land.

34001. Heavy clay land is not much good, I suppose ?—Well, you are more likely to get heavy clay land in the dairy districts of Ireland than light land.

34002. And that is not so suitable for the purification ? It is not so suitable.

34003. Of course, we find the same in England ; clay land is not so suitable for ordinary sewage ?—No.

34004. When you were speaking of acres just now, were you using the same acres as we have in England ?—Yes ; statute acres.

34005. That is the same as our acre ?—Yes.

34006. Do you happen to know whether there is much tuberculosis in cattle in Ireland ?—I have no practical knowledge, but I am told there is a great deal ; I am told that by veterinary surgeons who live in creamery districts.

34007. I think you said that the separated milk is given to calves ?—Yes ; in some districts.

34008. Is it boiled or anything before it is given to the calves ?—Well, it varies a good deal according to the districts. According to the decision of the Local Government Board ; they have compelled a good many creameries in times gone by to pasteurize the whole of their milk, and some of the creameries now do it continuously.

34009. So that this separated milk would be sterilized in most cases ?—Not sterilized but pasteurized, and there is practically no risk of tubercle.

34010. I have heard of cases in England of pigs being fed on this dairy waste without its being pasteurized, and the pigs have got an enormous amount of tuberculosis, and then they pasteurized the material and the pigs have not contracted tubercle ?—Yes. I do not think I mentioned this, that as regards the Ardagh effluent, there is no difficulty whatever in keeping the effluent down to the standards which have been suggested by the Commission, and from my point of view as a Public Analyst it would be much more satisfactory in Ireland to have a standard made applicable to creamery sewage effluents.

34011. (*Chairman.*) The standards which have already been recommended ?—Yes. I see no difficulty whatever by land treatment in getting an effluent down to the standard suggested.

34012. (*Mr. Willis.*) But do you see a difficulty by artificial treatment ?—It will be very expensive ; I have not seen a satisfactory plant at work for the treatment of dairy sewage. I know of one belonging to a creamery but they only use it for the purification of their piggery sewage. That plant is very satisfactory and I think it would work equally well for the creamery sewage if they would allow their waste to stand until it was thoroughly sour, and then boil it and then strain it.

34013. What can you buy land for generally in the neighbourhood of these creameries; how much an acre?—It varies a good deal; I really do not know the price.

34014. Within what limits would it vary; 30 to 100?—I think 30 to 60 or 80 in this particular district; in Ardagh land is very dear; the land is very rich in the Golden Vein.

34015. (*Mr. Tatton.*) It is a good farming district?—Yes.

34016. Good land?—Splendid land. I do not know any district in England, though I know most of the counties, where there is such a stretch of rich land as there is in the Golden Vein.

34017. (*Mr. Willis.*) Talking of land treatment, could you get the Commission's standard pretty easily if you had only clay land to use?—It is all clay land in Ardagh; all through the Golden Vein.

34018. (*Colonel Harding.*) When you spoke of your two acres to a thousand gallons, you had clay land in view?—Yes.

34019. (*Chairman.*) When this refuse sours; when the milk washings sour, I suppose the acid is lactic acid, full of lactic ferment?—Yes.

34020. Any solid that comes out is full of lactic ferment?—Yes.

34021. Would it be possible to kill that?—You can kill that by warming to 150° Fahr.

34022. Would it not be possible to make use of such a product as human food; it is not disagreeable; lactic acid has rather a pleasant taste?—Yes; still, the cost of evaporating, to my mind, is great.

34023. I am not proposing to evaporate; I am proposing to do what you suggest; let it ferment; take out the solids, and make use of those solids?—Yes; but with creamery waste everything goes into the sewer, the washings from the separators and the oil.

34024. I quite agree it would really have to be differentiated; I am supposing that you must keep the organic liquids free from all sorts of mess and dirt?—It can be done, but——

Mr. Walter Thorp, B.Sc., F.I.C., F.C.S.

17 Nov., 1913.

34025. It appears to me that there is something which could be used for human food, that is casein and lactalbumen, which ought to be used for human food?—There are practical difficulties in the way which are considerable. There is another point with regard to these standards. At the present time, with the suggested standards, I do not think, and I have had a good deal of experience of the Law Courts in connection with sewage pollution, that any judge would give a decree to abate a nuisance if it were shown that a serious effort had been made to conform to the standard that had been suggested. The tendency of all judges in Ireland is to do everything they can to encourage Irish industries, and although if a standard were fixed, the judge would compel the creameries to conform to it, he certainly would not give a decree if the effluent had conformed or nearly conformed to the standard. (This opinion has been modified by a decree given in the Rolls Court since the date of giving evidence).

34026. Then you think that our standards, the ones that have already been recommended, are satisfactory from your point of view?—The suspended matter is the most difficult one; it is very difficult to get down to it, but it can be done. I had a case in which I am told that prosecutions were being taken for pollution, and the effluent there does practically conform to your standard. I had one effluent which came out a little bit above the original suggestion, 1·5 parts of suspended matter per 100,000; it came out, I think, at 1·8, and I recommended the creamery to filter that through a peat filter, and they have done so, and now their suspended solids come below one part per 100,000. Even there I am told that action has been taken. I am quite certain they have no chance whatever of succeeding.

34027. (*Mr. Willis.*) You see an advantage in having a fixed standard, as I understand?—Yes; I am altogether in favour of a fixed standard.

34028. It is of use, you think?—I think three parts per 100,000 would suit us better in Ireland than two parts per 100,000, but it is possible to conform to the two per cent. standard.

34029. (*Dr. McGowan*) It is three per cent. per 100,000 as matter of fact; not two?—I was told it was two.

34030. (*Chairman.*) Thank you.

ONE HUNDRED AND SIXTH DAY.

Thursday, 19th March, 1914.

PRESENT:

Sir WILLIAM RAMSAY, K.C.B., F.R.S. (*in the Chair*).
Colonel T. W. HARDING, J.P., D.L.
Sir THOMAS STAFFORD, Bart., C.B., F.R.C.S.I.
Mr. F. J WILLIS, C.B.
Mr. R. H. H. KEENLYSIDE (*Secretary.*)

ALSO PRESENT:

Dr. GEORGE MCGOWAN.
Mr. C. C. FRYE.
Mr. G. B. KERSHAW.

Prof. A. R. CUSHNY, M.D., F.R.S. (Professor of Pharmacology, University of London), called in; and Examined.

Prof. A. R. Cushny, M.D., F.R.S.

19 Mar., 1914.

The following statement was handed in by the Witness:—

With regard to the concentration of lead, arsenic, and other metals, which is permissible in effluent water, no satisfactory estimations have been made. I have attempted to obtain some figures from the statistics obtained in chronic poisoning in man, and have found the following estimates for lead and arsenic. As regards chromium and zinc I have been unable to find any figures at all.

Prof. A. R. Cushny, M.D., F.R.S.

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Lead Content in Drinking Water (from Lead Pipes) which has given rise to Poisoning in Man.

—	Grains per gallon.	—
Sheffield, 1885	0·07–0·7	Sinclair White and Allen, cited by Thorne, *Practitioner* 37, p. 464, 1886.
Manchester, 1860	0·1–0·3	Calvert, *Chem. News*, 1861, p. 172.
Cases	0·01	Adams, *Trans. Amer. Med. Soc.*, 1852, p. 163.
Claremont	0·14–1·0	De Mussey, *Dub. Quart. Journ.*, 1849.
Bacup	0·1–2·0	Brown, *San. Record*, X., p. 464, 1889.
Case	0·0028	Oliver, *Lead Poisoning*, 1894.
Cases	0·18	Lacour, *Gaz. hebdom. de Med.*, 1902, p. 138.
Dessau	0·1–2·76	Wolffhugel, *Arb. a.d.k. Gesundheitsamt*, II., p. 484, 1887.
Huddersfield	0·01–0·84	Stevenson, *Guy's Hos. Reports*, XXVI., p. 473, 1883.
Huddersfield	0·14	Aird, *Brit. Med. Journ.*, 1884, 1886.
Keighly	0·6	Stevenson, *Guy's Hos. Reports*, XXVI., p. 473, 1883.
Cases	0·03–0·09	Lemmer (cited by Wolffhugel).

A common limit given in the text-books is 0·05 grains per gallon, but some suggest 0·1 per gallon, and others state that 0·05 has been shown to be injurious but refuse to place any limit which can be considered absolutely safe (Smith in Taylor's Medical Jurisprudence).

These figures are not quite satisfactory because, although very low figures are sometimes given (*e.g.*, Oliver gives 0·0028 grains per gallon), it is quite certain that in all cases the lead content varies enormously according to the time during which the lead stands in the pipes (from 1 to 276, Wolffhugel) and poisoning may arise from a very concentrated solution drawn in the morning, while the sample analysed may be taken later in the day, and may thus be very dilute.

These figures apply to drinking water for human beings, and it has to be recognised that they cannot be transferred to animals because much of the water consumed by man is purified by boiling, or the lead may be reduced by being precipitated by such bodies as tannin in tea, and much of the fluid taken may be obtained from other sources. It is probable that a water which would not be injurious to man, because taken in comparatively small quantities, might be deleterious to cattle, in which it forms a larger proportion of the total fluid taken, and still more to fish constantly living in it.

There is further every reason to suppose that different individuals vary in their susceptibility to lead, and that of a population drinking the same amount of water containing small quantities of lead, only a small fraction will show obvious symptoms, yet others may suffer in health, although the symptoms are more obscure.

Arsenic Content in Drinking Water which has given rise to Poisoning in Man.

Very small amounts of arsenic do not appear to be injurious. Thus the water supply of Leipzig is said to contain traces of arsenic, and several other cities are said to resemble it in this point.

On the other hand, arsenic in drinking water must not exceed a definite amount. The best known case of endemic arsenic poisoning from water is presented by Reichenstein, in which the population shows very definite symptoms. The water contains 0·00255 grains $As_2 O_3$ per litre or 0·17 grains per gallon. Some of the wells are said to have as much as 1·4 grains per gallon, but these are not used (Geyer, *Arch. f. Derm. & Syph.*, 43, p. 221).

In the Manchester epidemic of 1900, the beer contained as much as 1·3 grains per gallon. In Halifax, beer containing 0·025–0·0625 grains arsenious acid per gallon gave rise to poisoning in 1902. In Hyeres an epidemic arose in 1887–8 from wine containing 5·5 grains per gallon.

The difficulty in using these figures as a basis lies in the fact that the amount taken per day cannot be ascertained. The Reichenstein water gives the best idea, but here again the figures cannot be applied to animals, as the population consumes other fluids than water. And the amount of arsenic which may be contained in water without injury to fish is quite unknown.

34031. (*Chairman.*) You are Professor of Pharmacology at University College ?—Yes.

34032. And you have been engaged more particularly on pharmacology for a very long time ?—Yes, for nearly twenty-five years.

34033. Both in America and here ?—Yes.

34034. You have put in a full report stating that, with regard to the concentration of lead, arsenic, and other metals, which is permissible in effluent water, no satisfactory estimations have been made; and you have also given certain figures. Would you like this report to go into our documents in full; it represents, as far as you know, our knowledge on this subject ?—Yes. Of course, there are more of these cases; one could find more cases of lead poisoning, and that sort of thing, but they all come to the same thing; there is just the same indefiniteness in each of the reports, so I have not put them all down. I got rather tired of the matter, and have looked up to about 1900, and one or two cases since, but the results are equally indefinite.

34035. As regards poisoning animals with lead, is much known; has much been done ?—About all that is known is that animals have been poisoned with lead—cattle chiefly; cases of cattle drinking from lead water and eating lead grass, and so on.

34036. Are the symptoms the same in cattle as in man ?—Well, very largely. Paralysis and colic are two characteristic symptoms.

34037. No experiments have been made with fish, I suppose ?—No, not so far as I know.

34038. Do you think one could take it that the poisonous effect on animals can be reckoned according to their weight, or is there a specific action on man, different from that which there is on animals ?—The poisonous amount could not be reckoned from man to animals, because the conditions are so different. Man only takes a part of his fluid from the lead-impregnated waters, whereas an animal would take a much larger proportion, and particularly is that so in the case of fish. It is very difficult to give any concentration, because fish are peculiarly susceptible to anything which interferes with the passage of oxygen through the gills—even an infinitesimal amount—and some drugs are much more poisonous to fish than to mammals on account of the blocking of the gills.

34039. But is there anything in water containing lead which would cause the gills to be blocked ?—The lead might itself, of course.

34040. Is it a mechanical blocking or a physiological effect ?—Anything that causes a precipitate on the gill surfaces. At least, that is the idea. For example, many of the fish poisons are quite harmless to man and other animals, because by causing a precipitate on the gill surfaces they prevent oxygen passing through, so that one cannot argue in the least from what is poisonous to man to what is poisonous to fish.

34041. I suppose an experiment conducted on fish would not be in the least difficult ?—No, very simple.

34042. I see the figures given on the first page of your statement are very divergent. For example, you set out from ·1 grains per gallon to 2·76 grains per gallon. Does that mean the maximum quantity found, or the quantity that is poisonous ?—They are the estimates that are given. They have taken the water at different times—in the morning and evening perhaps; or perhaps they have taken it from different faucets, and the 2 grains would be obtained probably from water that had stood in the lead pipes over-night. The ·1 would be got later.

34043. From running water ?—After it had run.

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34044. But it does not imply that ·1 is a lethal dose ?—No, one cannot say it is, although all the authors regard that as the dangerous point; but it is not satisfactorily established.

34045. As regards lead, it is reckoned to be a cumulative poison ?—Yes.

34046. One can go on taking it day after day, and it stays in the system, and is not eliminated ?—Yes.

34047. So that long exposure to a weak lead water would be a dangerous thing ?—Yes, so much so that most of these writers on lead poisoning refuse to give the lowest limit altogether. They used to give pretty regularly one-twentieth of a grain as the amount which poisoned, but now they refuse to give any limit at all.

34048. So far as we are concerned from the trade effluent point of view, you regard the subject as one which has yet to be investigated ?—Entirely! So far as trade effluents are concerned, there is no more knowledge now than there was thirty years ago, or twenty-eight years ago, when Koch gave one-twentieth of a grain per gallon; but it was quite unsatisfactory, owing to the fact that one does not know how much the effluent is diluted by the water it flows into.

34049. Would the experiments be difficult ?—Oh, not at all.

34050. They simply have not been made ?—They have not been made. The hygienic people have been so busy with bacteria for the last twenty-five years that they have not had time.

34051. Arsenic is not reckoned a cumulative poison ?—No; not in the same way. Very small quantities of arsenic appear to be quite harmless, because it is found in some city supplies. For example, it is said to occur in Leipzig, and it is also stated by some people to occur in Boston, in the United States, in the water, and it has been found in Boston people in larger amounts than almost anywhere else. It has several times given rise to some difficulty in diagnosis, but it is quite harmless in these small amounts. In some larger amounts it apparently has a bad effect, but where the limit begins I have no idea at all.

34052. It is not known ?—It may depend a good deal upon the general nutrition of the people. There is evidence to lead one to suppose that with badly nourished people the limit is lower than with better nourished people, and probably the same would be true of animals.

34053. Would the cases of arsenical poisoning in animals and men run more parallel than with lead, or is it open to the same argument ?—No, about the same I think.

34054. The effect is pretty much the same on both ?—Yes, I think so.

34055. I suppose experiments could be made on animals with a fair possibility of deducing the effects on man ?—I think so, yes; again excepting fish, of course.

34056. They have not been made ?—They have not been made.

34057. In the case of the Manchester epidemic, where there was a fairly large quantity of arsenic in the beer, were the people really poisoned ?—Oh, yes; there were deaths, and thousands of cases of poisoning.

34058. And that gave rise, I think, to the appointment of a Committee or Commission of some sort ?—A Commission, yes, and I looked up what they found. They found that there was a large proportion of arsenic, sometimes as much as one-third of a grain per gallon, but the beer—although it afforded a large amount of the fluid—did not afford the whole of the fluid of the people, so it is impossible to say how much they were really taking.

34059. (*Sir Thomas Stafford.*) Do you remember the quantity of arsenic found in the beer ?—1·3 grains was found sometimes.

34060. (*Chairman.*) A very similar quantity gave rise to poisoning in Halifax in 1903 ?—Yes.

34061-2. About one-fortieth of a grain per gallon ?—Yes.

34063. Have you noticed that in the Report of the 1868 Commission, they give a limit for arsenic ?—What do they give ?

34064. I have forgotten what it is.

34065. (*Dr. McGowan.*) It is ·05 parts per 100,000.

34066. (*Chairman.*) The water should not contain more arsenic than that. We are rather wondering where they got that information from; we cannot find it—That is one-twentieth ?

34067. One-twentieth of a grain per 100,000 ?—I have prepared all my figures in terms of grains per gallon.

34068. (*Dr. McGowan.*) They have one-twentieth of a grain per gallon.

34069. (*Chairman.*) We have it here; I will read it out: "Any liquid, which in 100,000 parts by weight, contains whether in solution or in suspension, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic."—Yes, it is about one-thirtieth of a grain per gallon. I should not like to say anything about that without more calculation, but that would be about what the books were recommending at that time. They acknowledged that one-twentieth of a grain was dangerous, or doubtful at any rate, but I do not think it was intended to say precisely one-thirtieth. A good many people said one-twentieth should not be allowed. Ringer, for example, said in his text-books that one-fifteenth of a grain was poisonous, and they probably halved that I think.

34070. That is perhaps how they got at their figures ?—Yes, it was the general impression at the time.

34071. Do you think we should make a similar recommendation ? I am afraid we cannot do it, but should we suggest that a similar recommendation should be made later on by our successors after the subject has been investigated ?—Yes, after they have examined it I think.

34072. It would be possible to put a limit of that sort on ?—Yes, I think so.

34073. Then we come to copper. Has anything been done with regard to poisoning by copper ? There have been many cases of poisoning by copper in large quantities, of course ?—Yes, it is poisonous, more particularly to some of the lowest forms; I do not think it has been found so poisonous in the higher forms.

34074. Is not the question rather an important one from this point of view, that, to destroy certain algæ copper is added to the water ?—Yes.

34075. No doubt some of the copper remains dissolved in the water, and might be drunk by human beings ?—There is no danger from human beings drinking it. It exercises what is called oligo-dynamic action, in which it cannot be found chemically even; it is present in such minute quantities that it gives no chemical test.

34076. There would be no danger you think ?—Absolutely no danger for a man or the higher mammals. How a fish gets along one hardly knows, but I do not think it is damaged by this small amount.

34077. Again we might say that no investigation has been made as regards the effect of copper on fish ?—I think so. In this small amount there is no danger to mammals, but how much danger there would be to fish and plants I do not know.

34078. Again, in copper districts, the copper sulphides and oxides get into the water as sulphate, and one sees blue water. I do not know whether such streams are drunk after dilution, or after flowing into a main river, but there must be quite estimable quantities of copper ?—Yes.

34079. Again we might say that we do not know its effect ?—I am afraid that, if it is poisonous at all, it would be poisonous in such a marked way that people would not drink it. It causes vomiting, and there is no such thing as chronic copper poisoning.

34080. Is it a cumulative poison ?—No, it is not absorbed. Apparently there is no particular danger in it.

34081. There are one or two other elements which might be found in water—chromium for example ?—I cannot say anything about that.

34082. You know nothing about that ?—That is quite unknown. The only poisoning one knows is from chromic acid dust.

34083. It is bichromate of potash you get into the water, most likely ?—Yes.

34084. Which comes from tannery yards; it would probably be reduced pretty quickly ?

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34085. (*Dr. McGowan.*) We tested a tannery for that a few years ago. It is chromate or bichromate.

34086. (*Chairman.*) That is a poisonous substance in large quantities ?—The only form of chromate poisoning I am at all familiar with is a curious form that occurs in some factories, in which a dry dust apparently is inhaled and it attacks the cartilage of the nose. But what chromate would do if it were swallowed for some time, no-one knows at all. It is quite unknown.

34087. They are also trying to keep manganese out of water; there is a considerable quantity in German waters ?—Yes, all of these things disturb the digestion in sufficient quantities, even if they do not do anything worse, except lead and arsenic; but they have occurred so seldom at present, or have not occurred at all in the case of chromates practically, that one has no knowledge of them at all.

34088. I know they take considerable pains to rid the waters which come from the neighbourhood of Leipzig and Berlin of manganese. I suppose they find it is deleterious ?—Oh, yes, I have no doubt it would be if taken for any length of time, particularly in the case of animals who would not protect themselves by vomiting if they got too much.

34089. Is that so ? Do animals not vomit, as a rule ?—The dog and cat do, but the horse and cow have very great difficulty, and do not vomit at all. There, again, you have a difficulty in estimating the action, because a man empties his poison out when he takes it, whereas these domestic animals do not; it lies in the stomach and intestines.

34090. I think it comes to this, that there is great room for investigation as to the allowable amount in water, if there is an allowable amount ?—Yes, the whole thing is supposititious—the knowledge we have.

34091. At the present moment, what should be the position of the Commission ? Can we in our Report say anything whatever about the presence of such active mineral poisions in water ?—I think it would be a pity to say that any definite amount was known to be poisonous, and equally so to put on record that you thought a certain strength was safe. As a matter of fact, no safe strength is known.

34092. Could we go so far as to say that these poisons must be totally excluded from waters which are to be drunk ?—I do not know that that is necessary. In the case of arsenic it is not. I think your only position is to state that you are unable to give a lower limit, and that the subject requires investigation.

34093. (*Sir Thomas Stafford.*) How far is lead a cumulative poison ? It is a cumulative poison ?—Of course, it is a cumulative poison in this sense. You can take lead in quantities which are quite harmless if you take them for one day, and you can take an amount of lead which is absolutely harmless for a week perhaps; but if you take the same quantity for a month or six months it produces symptoms. In that sense it is a cumulative poison. As to whether it accumulates in the system, or whether it is the cumulative effect on the system which is injurious, views are still a little indefinite. It may be the effects which accumulate, and not the poison; but with lead I think there is very little doubt it does accumulate in the liver and other tissues.

34094. (*Chairman.*) There are cases of polluting matters of all kinds, certain kinds especially from the neighbourhood of paper works, which contain caustic soda in a polluting form. Is there any objection to water being alkaline from caustic soda or lime ?—I do not think one has got a water so alkaline as to affect the higher animals, but I do not know how a fish gets along in a highly alkaline water.

34095. That again has not been tried ?—It has not been tried.

34096. (*Sir Thomas Stafford.*) We do not know the action of lead upon fish either ?—Not at all, but fish are peculiarly susceptible to certain forms of poisoning that animals are quite immune to. Many fish poisons, perhaps most of them, are tannic acid, and are quite harmless to man or any other animal, but block the gills of the fish apparently.

34097 (*Colonel Harding.*) I only want to ask one question. Would the combinations of arsenic in water be in the form of soluble matters, or matters in suspension ? Would the arsenic be present in suspension or in solution ?—It might very well be in solution, and then it would be much more important than if in suspension.

34098. Do you think it would be more likely to be in suspension than in solution ?—I could not say. In the Reichenstein water, which I mention in my precis, it is in solution.

34099. (*Chairman.*) It occurs to me—I may be wrong—but supposing there was in water such a thing as arsenical iron, which might happen. Arsenical iron pyrites is insoluble in water, but I do not know what would happen if it were taken into the system. It might dissolve ?—But it would not dissolve from the beginning. It would be much less poisonous, therefore, than if it were in solution.

34100. But it would be in suspension in the water, no doubt ?—Yes.

34101. But it would not be so apt to be poisonous if it had to be acted on afterwards by animal fluids ?—No, but there again, it depends on the fineness of the suspension, I take it.

34102. It is found that very finely suspended solids are absorbed in the bowels ?—Yes, they tend to be, and they are also dissolved, acted upon by the fluids.

34103. (*Colonel Harding.*) My reason for asking the question about suspension or solution was that a suggestion has been made that, if the Commission were to limit the amount of suspended matter in an effluent, probably the reduction of suspended solids would obviate the danger to cattle and fish of poisoning from lead or arsenic. Do you think the limitation of the amount of suspended matter in an effluent might be effective in preventing arsenical poisoning ?—I should scarcely suppose so. It depends again on the form. If you said, for example, that the amount of suspended matter must be less than so much, in connection with some forms of manufacture you might have large quantities in solution of arsenic or lead—lead in particular.

34104. (*Chairman.*) That is so; yes.

34105. (*Sir Thomas Stafford.*) From the point of view of our present knowledge, or want of knowledge, do you think it is very desirable that further investigations on all these matters should be undertaken ?—Yes, I was quite surprised to find how very little we knew about it when I began to turn it up.

34106. From the point of view of men, animals and fish ?—Yes, I think so.

34107. (*Colonel Harding.*) Might I ask Dr. McGowan whether he can give us the considerable amount of arsenic he found, not in an effluent, but in a river ?

34108. (*Dr. McGowan.*) In a river water, a small stream in the neighbourhood of Accrington, near a works where there was an arsenical preparation for sheep-dipping, the river water contained 7 parts of arsenic per 100,000. I cannot give the exact figures but there were about 7 parts per 100,000.

34109. (*The Witness.*) How much is that per gallon ?

34110. (*Dr. McGowan.*) About 5 grains per gallon.

34111. (*The Witness.*) That is much more than was found poisonous in Manchester.

34112. (*Colonel Harding.*) It was tremendous.

34113. (*Dr. McGowan.*) Would you ask the witness if he knows anything about zinc ?

34114. (*Chairman.*) Zinc is a poisonous metal, is it not ?—It is not so poisonous, nothing like so poisonous, as lead. It is a self-protective sort of poison. If present in any large quantity, it causes sickness and vomiting, so it is not nearly so dangerous as the others. There is a form of chronic zinc poisoning, but it only occurs from the fumes apparently in the so-called brass-founder's ague. Whether zinc could be taken in solution for any length of time is also unknown.

34115. I remember that cattle which eat grass near zinc works are supposed to get diarrhœa. I do not know whether it is serious or not, but their digestion is put wrong ?—I should not be a bit surprised if that were so, but in all these metallic poisons one's great difficulty is that one never knows which metal is to blame. For

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example, in the brass dust ague, it is generally supposed to be copper which is to blame, but it is really zinc I think. I think I have heard of zinc cattle poisons, but the question is whether there was not arsenic present as well.

34116. Are tin and antimony serious ?—Antimony is serious, of course. Tin is not so serious as it is generally reputed to be, although it is also poisonous in quantity.

34117. Antimony would rarely get into water in a soluble state. Its compounds are practically insoluble ?—Quite insoluble.

34118. And, of course, on the question of suspension—small quantities suspended—the question would be whether they would be absorbed into the system ?—Antimony would be, of course.

34119. It would ?—Of course.

34120. It would dissolve ?—Oh, yes.

34121. I do not think the tin streams are ever drunk.

34122. (*Dr. McGowan.*) None we know of.

34123. (*Chairman.*) Oxide of tin is insoluble ?

34124. (*Dr. McGowan.*) Yes.

34125. (*Chairman.*) What about oxide of iron ?—I do not think it is a serious poison.

34126. Then it comes to this, to finish up what we have said before, that this is entirely a question for investigation, especially in regard to fish ?—Yes.

34127. And very little is known, and in the present state of our knowledge we cannot make any definite report upon it ?—No; very little is known. I should think that everything is pure guess-work practically.

34128. Thank you, very much, for coming and giving us the benefit of your experience.

Councillor Harvey Robinson, Mayor of Ossett; Alderman Gledhill, Chairman of the Sewage Disposal Committee of the Dewsbury Town Council; and Alderman Richard Johnson, J.P., Chairman of the Sewage Committee of the Bradford City Council, called in; and Examined.

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34129. (*Chairman.*) Well, gentlemen, for the sake of completeness, I ought to ask you your names and occupations. Mr. Robinson, you are Mayor of Ossett ?—(*Councillor Robinson.*) Yes.

34130. And Mr. Gledhill, you are Chairman of the Sewage Committee of the Dewsbury Town Council ?—(*Alderman Gledhill.*) Yes.

34131. And Mr. Johnson, you are Chairman of the Sewage Committee of the Bradford City Council ?—(*Alderman Johnson.*) Yes.

34132. You wish to represent to us certain points in connection with the admission of trade effluents to sewers ?That is so.

34133. Have you any statement to make ? I do not quite know how to question you ?—Not a written statement, but the Mayor of Ossett, if you like, would make a statement, or I would make a statement, subject to cross-examination. Our statement would be brief, and on anything I say, if there are any questions you would like to ask me, I should be happy to answer.

34134. I think that would be the best method of procedure, for the Mayor of Ossett to make a statement ?—(*Councillor Robinson.*) I will follow you, Mr. Johnson. (*Alderman Johnson.*) Very well! If the Mayor of Ossett desires me to do so, on behalf of the Bradford Corporation I wish to make representations to the Royal Commission on the question of dealing with trade effluent, and to ask them if they could recommend in their final Report that local authorities may be empowered to charge for the admission of trade effluent. In dealing with Bradford—and I leave it to the others to deal with their own difficulties—in Bradford 50 per cent. of our total flow is from traders. Some of them buy the water from Bradford, and some of them pump the water.

34135. By means of artesian wells ?—Yes; they have sunk in their own premises bore holes, and are able to get water for their purposes. Taking our flow of sewage first, it is 16,000,000 gallons. You have some experience of the difficulties of Frizinghall, because you have been there.

34136. I have been there.—Taking our flow of trade effluents, we have 2,000,000 gallons of wool combers' effluent, which is a very difficult matter to deal with, and 6,000,000 gallons of effluent from dyers, finishers and piece washers. The difficulty we have in dealing with the trade effluent is its variety, and during the last fourteen years, not only has the flow increased, but the sewage itself has got 20 per cent. worse. That is due to different traders adding to it, and not due to much increase in domestic sewage. It has been suggested that the local authority should be satisfied with a preliminary treatment, but my experience of the last eighteen years is that a preliminary treatment is generally a farce. It is done occasionally when it is profitable, but if it is unprofitable it is allowed to escape into the sewer, and we think we ought to have power to charge, for this reason: If the wool combers had to treat it themselves, it would cost, according to a return issued by Dr. Wilson in 1911, 1s. per 1,000 gallons. We receive payments from a few for a small quantity, only amounting to £300 or £400 in the total, and the treatment of wool combers' effluent alone would cost us far in excess of the total rates we get from the firms. I have tables which I will hand in to you.

34137. (*Colonel Harding.*) You mean rates for all purposes ?—Rates for all purposes. Then as to the dyers' effluent, if it only cost 1d. per 1,000 gallons, we should not get as much in the total rates as we should have to spend in treatment of their effluent. Therefore, it seems to be unfair that these traders should have an advantage over other people. In fact, why should a firm, because they deal with liquid trade waste, have an advantage over a firm that deals with a dry trade waste ? We are not called upon to remove engine ashes from the premises of any firm, nor grains from a brewery, which is their trade waste, nor the result of excavations and old building material. It is only when it becomes liquid that they try to put it into the drains. Some of them have an old prescriptive right, which we tried in 1897 to overcome, but were unsuccessful. But with all new firms, we try to get control over them. If the dyers had to give a preliminary treatment to the 6,000,000 gallons a day they put in, it would be almost impossible for them to find accommodation adjacent to their works, even at a reasonable price. Therefore, it would be cheaper for them to pay us than to put down works to treat it at 1d. per 1,000 gallons. When it comes to the question of wool combers, if we compel the wool combers to treat, they have generally a very limited space, and it sets up, as you will know Sir William, a very bad nuisance in the neighbourhood by cracking it with sulphuric acid, and allowing it to escape in the atmosphere.

34138. Yes.—In their case, we want to prevent a number of sewage works being dotted up and down the City, and we think it is cheaper, and could be done very much better at one centre as we propose at Esholt, and are partly doing it now at Frizinghall.

34139. You propose a separate system of sewage pipes ? No, to take it altogether—the domestic, the wool combers' and the dyers' effluent.

34140. But if you are to treat wool combers' effluent for the purpose of recovering the fats on a large scale, would it not be better to keep the trade refuse, such as the dyers', separate from the common sewage ?—If we could keep the dyers out, it would probably. There is no fat in the dyers' effluent, but by having the wool combers' effluent mixed with the ordinary domestic sewage, we recover the fat from both.

34141. You do that at present ?—We do that at present. We have been able during the last twelve years to very gradually develop that side; otherwise our sewage rate would be very much more than it is now. It is rather less than 5d. In Bradford we are in a very unique position, and I cannot complain that the sewage rate is excessive, but I do suggest that if a manufacturer had an unrestricted right of entry into the sewer, it would not only upset our works, but those works were not

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constructed for the purpose of dealing with manufacturers' effluent, and there are works in our neighbourhood which have been constructed only to deal with domestic effluent, and no trade effluent goes into the sewer at all, so that if a manufacturer can obtain a right to go into that sewer, their work would be entirely upset. I am going to hand in one or two cases based on Dr. Wilson's report. I am not giving the names, but I will give a few typical cases. There are thirteen of them altogether, but I need not mention all of them. In case No. 1, we receive from a wool comber 2,809,000 gallons per annum. The total rate he pays, including everything, the total district rate and poor rate, the municipal rate, is £655 per annum. Our proportion is £30, which the Sewage Committee get, and if he had to treat it himself it would cost him £140. Now, in another case—case No. 2—we get from the wool comber 4,826,000 gallons per annum, and his total rate is £208. Our proportion is £10, and according to Dr. Wilson's figures, it would cost him £241, so that we do not get as much from him for every public service as it would cost us if we had to give a final treatment to it. We are not at present giving a final treatment. In the next case, the quantity is 1,376,000 gallons per annum, and his total rate is £35 11s. Our proportion is £2, and it would cost £68 to treat. I need not continue all these cases, but we have a dyer, bleacher and merceriser, from whom we get 130,000,000 gallons per annum, and their total rates are £590. Our proportion is £27, and at 1d. per 1,000 gallons —and no-one can say 1d. per 1,000 gallons is an excessive price in dealing with dyers' effluent—it would amount to £540. It would cost us £540, £27 is all we get towards it, and £590 is all the contribution they make. The next are dyers, bleachers and finishers, and we get from them 34,000,000 per annum. The total rate is £102. Our proportion is £5, and at 1d. per 1,000 gallons it would cost £141. We have, in case No. 12, carbonising and wool-washing, where there are 6,500,000 gallons per annum, and the total rate is £78. Our proportion is £4, and the actual cost at 3d. per 1,000 gallons—because carbonising and wool-washing effluent is half way between dyers' effluent and wool combers' effluent—would be £81. Another bleacher and dyer sends 163,000,000 gallons per annum, and the total rate is £1,418. Our proportion would be £66, and if we were able to charge 1d. per 1,000 gallons we should get £680. It would cost £680, and we get £66 towards it. I do not think I need read the whole of them, but since I came before you a few years ago, added experience has not changed my opinion about the matter. I think I gave evidence before the Royal Commission twelve or fourteen years ago, and I am more strongly convinced than ever, with my eighteen years experience, that manufacturers ought not to be granted a preference over any other kind of trader merely because they have a liquid trade effluent. They are getting far more public service at the present time than they are paying for, and if they had an unrestricted right of entry into the sewer they would get far more public service than they are getting now, and would not pay any more for it. It would upset not only our works, but I believe all other sewage works, and we do not seem as if we have control over them. We not only want to have a payment, but we want control—control in this way, that they shall regulate during the working hours the letting off of their trade effluent. We do not want the flushing down of a 1,000,000 gallons of wool combers' effluent at nine o'clock in the morning, and five and six o'clock at night. If it were spread over the whole of the day, we should be better able to deal with it at our works, but if we get the combined flow of a number of effluents about three times in the twenty-four hours, it is difficult to deal with. It is difficult to add the necessary amount of acid, and it is difficult to control by the men, and we suggest that we should have power to regulate the flow. I think I have now practically covered the ground, and the Mayor of Ossett and the Chairman of the Dewsbury Committee will perhaps put before you, from their point of view, their difficulties. For myself, I should be glad if you would question me on any point.

34142. Perhaps the Mayor of Ossett will tell us his views?—(*The Mayor of Ossett.*) I do not think the Alderman has left much for me to say, except to deal exclusively with the thing as it affects the Ossett Corporation. I coincide with a large proportion of what he has said, and I may say it is a matter which I have been taking an interest in for a considerable time, not so much from the scientific and technical side, but from the economic and financial side. I do not happen to be Chairman of the Sewage Committee, but Mayor for the moment, and I think I ought also to say that at the moment we have a Bill in Parliament this year dealing with this very question, and seeing that I have taken some interest in the matter by calling a couple of conferences of the authorities in the West Riding, Alderman Johnson thought it would be wise that I should accompany him to the Commission to-day. We are hoping that in the next few months we shall have our own house in order, and that things will be brought to a more equitable point. We are not animated with any animus at all against the traders of our township. We all know who are engaged in business how much the prosperity of the town depends on the trade and the traders of the town, and we are not seeking in any way to hamper or impede the progress of the town from the commercial standpoint; but we do really think the treatment of this effluent is a trade charge, and ought to be borne by the trade itself. As Alderman Johnson has said, a man that deposits his liquid refuse ought not to have a preference over a man who has a refuse of, may I say, a more tangible character. I have a few figures to put before the Commission which apply distinctively to Ossett. A Committee was sitting upon this matter, and these are their findings. We have an area of 3,200 acres, and a population, according to the last census, of 14,080. We have a dry weather flow of 1,000,000 gallons per day, which is far in excess of any other town you can point to. It has been ascertained that the trade is giving us about 788,800 per day, which means that three-quarters of our daily dry weather flow is trade effluent. Our rateable value for all purposes is £56,548, of which domestic, municipal and warehouses, amount to £37,144. I will hand this document in later if it is desired. I also prepared a statement for the Non-County Boroughs Association last year, and I prepared a further statement, intending to present it to the Municipal Corporations Associations, which however was not presented to them but has been published; and, if the Commission would care, I have a few copies of it printed, and should be glad to hand them to the Commission.

34143. I think it would be very useful.—As I was saying, we have a rateable value for domestic, municipal and warehouses, of £37,144; for mill owners of £7,852; for collieries and railways, which give no effluent at all, of £7,775; and for agricultural of £3,777. The mill owners, who give a trade effluent, have only a rateable value of £7,852, which is very significant. There is only £7,852 worth of mill property in the township.

34144. Out of the total?—Out of the total of £56,548. Now the average cost of working expenses, based on the last four years working, is £1,300 a year. The interest on loans and sinking fund is £2,100, making a yearly cost of treating the double effluent of £3,400. Our sewage rate is about 1s. 6d. in the £, and the domestic contribution to our domestic rate is £2,786. If the domestic were paying on the basis of user, they would only be paying a matter of £868. Taking it on the other side, the mill owners' contribution to the rates is £589. If they were paying on the basis of user, they would be paying £2,537 a year, so that the mill owners are paying less than they should by £1,948; or, to put it the other way, the general public, the rate payers, are paying more than they should by £1,948. The cost of treatment of sewage per 1,000,000 gallons is £11 5s. I should like to give you particulars of one or two cases in Ossett, in the same way that Alderman Johnson has given one or two in Bradford. I will give no names, but put them under letters; it is wise, I think you will agree with me, that no names should be published. We have Messrs. X. rated at £297. They have a yearly effluent of 7,000,000 gallons. Now, paying as they do on the basis of the rateable value of their property, they are contributing for sewage purposes £22 5s. 6d. If they paid on the basis of user—that is £11 5s. per 1,000,000 gallons—they would have to pay £78 15s. 0d. They are paying less than they should pay by £56 9s. 6d. In another case they are rated at £280, and are giving a yearly effluent of 9,560,000 gallons. Now, they are paying through the rates £21, and if they paid on the basis of user, they would be paying £107 11s. and they are paying less than they should by £86 11s. Now I should like to give another case, which is one that

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came to my notice in peculiar circumstances. You will understand it is very difficult to ascertain the amount of the effluent from particular mills. Where the township supplies them with all the water they use, it is a comparatively simple matter to ascertain the quantity of effluent, but where they have a stand-by to draw from, we find it is difficult to ascertain the quantity of effluent. We had an idea that this man was giving a tremendous amount of effluent, but we had no means of checking it until by an accident, we had it later confirmed from his own lips that he was giving us 14,000,000 gallons per year. He is rated at £101 a year and giving us 14,000,000 gallons of effluent. He is paying for sewage purposes £7 11s. 6d. per year. If he paid on the basis of user, he would be paying £157 10s., so that he is paying £149 18s. 6d. a year less than he should. Our rates are 9s. 4d., and that man for all purposes is paying 101 × 9s. 4d. How much is that? (*Alderman Johnson.*) About £45. (*The Mayor of Ossett.*) Call it £50 in round figures. That man, for all purposes—highways, education, poor, district and borough rates—is contributing less than £50 a year to our total rates, and the giving of the service costs £157 10s. On those grounds we consider there is a gross injustice perpetrated on the general ratepayer, which ought not to be perpetrated, and that it is time it came to an end. We consider local authorities should have power to make a charge, and we think it would go a long way towards solving the whole problem. In my opinion—and I am expressing also the opinion of my Council—the matter of preliminary treatment becomes a matter of less significance if the authorities have power to charge, because they would have power to charge differentially on the character of the effluent. If a man is treating his effluent in a partial way, he would have less to pay to the Corporation for taking it from his works and completing the treatment and disposing of it.

34145. Who would be the judge, may I ask, as to the amount of purification?—I suppose his effluent would have to be subject to an analysis, and it would be determined accordingly. (*Alderman Johnson.*) Or there might be a Committee, or any independent authority. (*The Mayor of Ossett.*) I suppose there would be some authority set up to determine this sort of thing.

34146. (*Colonel Harding.*) What Committee do you mean?—(*Alderman Johnson.*) An appeal to the Sewage Committee by Counsel or by himself personally.

34147. Do you suggest that the decision of the Sewage Committee should be final?—If the decision of the Council was to charge a trader 3d., and he felt aggrieved, he could have a right to go to the Sewage Committee with his evidence to prove that we were charging him too much, and we should be obliged to bring in our evidence that we were charging him too little.

34148. Your suggestion is that the charges should be left absolutely to the discretion of the charging body?—Of the local authority.

34149. Without appeal outside it?—(*The Mayor of Ossett.*) In our Bill before Parliament we are following the precedent of Morley's Bill last year, and in that of course the thing is settled; the whole questions connected with it are settled by representatives from the Council and from the traders themselves. In the event of these combined bodies being unable to settle the question, the whole thing is to be sent to the Local Government Board. The thing has to be determined before an arbitrator appointed by the Local Government Board.

34150. (*Chairman.*) That is fair?—Yes, and it is a thing which I agree. I think it is only fair that they should have some say in the final settlement of the price.

34151. Is it likely that a difference of opinion will arise?—I think probably it will; there will be some difference arise. (*Alderman Johnson.*) You have agreed with your traders. (*The Mayor of Ossett.*) In regard to Ossett, the positon is this with regard to our traders. We had two conferences with them, and they had several conferences amongst themselves, and we tried our best to come to an amicable settlement without going to Parliament, but we found that impossible simply because a number of the traders stood out, and it would not be fair for a number to agree and a number to stand out. At last the traders themselves came to a decision something like this; they passed a resolution that they were unable to deal with the question, and threw the work on the Town Council to deal with it in the way they thought best, and appointed three of their number to receive any communication the Town Council was prepared to make, and, if necessary, to call a further meeting. That was communicated to us, and as soon as we got our proposals in draft form for the Bill, we communicated it to those three individuals, and they considered it very fair. We have submitted the Bill to them as it stands presented to Parliament, and they think our Bill is fair and equitable in all its propositions, and have decided not to call a further meeting. I do not know that I have much more to say, except that you know, as well as we know on the spot, that sewage treatment is a very difficult problem, and the difficulty of sewage treatment undoubtedly is intensified by trade effluents.

34152. What sort of trade effluents have you?—Ours are largely dyeing and washing, and carbonising, and things of that character.

34153. Have you wool?—No, we have no wool at all. There is no grease in ours to recover, and we have a 1s. 6d. rate, and at Bradford a 4d. rate, but our effluent is tremendously charged with acid, it is awfully strong with acid. It is neutralised a little in coming in contact with the domestic effluent, which is alkaline; but from rag-washing and that sort of thing we get a tremendous amount of salts. As a matter of fact, in our little Borough, in the last year available for figures, we had 4,850 tons of sludge, which cost 3s. a ton before we got rid of it, and it was only with the utmost difficulty that we got rid of it. As a matter of fact, it became impossible, and we had to call in other means of getting rid of it. We have bought a kind of valley, and are pumping it there, and leaving it there to settle and dry. It will last ten or a dozen years. It became a nuisance, and when we were giving 1s. and 1s. 4d. a load for the sludge to be taken away, any farmer would take it to find his horses something to do, and deposit it at the nearest possible point, but we found that the loads of sludge deposited here and there became a nuisance, and we had to find other means of disposing of it.

34154. I should like to ask, Alderman Johnson, is the recovery of fat remunerative to your Corporation?—(*Alderman Johnson.*) If we had only that to deal with, yes.

34155. If you separated this from the sewage, for the purpose of dealing with the fatty liquors, and for dealing with that only, it would be remunerative?—Yes, I think we could make a profit out of extracting grease from the woolcombers' effluent if it were sent to one centre, but the difficulty is sending it to one centre, because they are scattered all over the city, and it would mean miles of new drainage. Besides, in our neighbourhood we have a certain amount of fat from domestic sewage. The people who are employed in the wool trades, their clothing is dirtier and greasier than would be the case in an ordinary factory, and we find that in certain parts we have as much as 2 tons per 1,000,000 gallons in domestic sewage on a washing day. We find it on the Monday, less on Tuesday, scarcely present on Wednesday and Thursday, and it gradually grows less until it is Monday again, where we have been successful for the last 12 years in extracting grease.

34156. I suppose the amount which pays depends largely on the price of recovered grease at the time?—Yes; we have to spend £15,000 in sulphuric acid. (*Alderman Gledhill.*) I have very little to add to what my two friends have said. Ours is a similar case with regard to the rating. I have brought no figures, but I know we have one case—a wool scourer and dyer—who pays a sewage rate of £9 a year, and the rate it costs us is about £130. He pays to the total rates £75, and it costs us something like £130 a year to treat his trade effluent. But in our case we are not so bad as many of our friends. We find difficulty in getting manufacturers to agree. We find some of them very amenable to reason and willing, and my mission here to-day along with my friends is to ask you gentlemen to recommend in your final Report that authorities shall be allowed to charge. I am not so keen on the local authority having the whole say; the question might be submitted to arbitration if the manufacturers thought they were wrongly dealt with, and the Local Government Board would be a very good tribunal to appeal to. I think we should then get justice on both sides. We have about 250,000 gallons a day that is paid

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for; the manufacturers are willing to pay themselves—about six or seven small traders—and before they go to the expense of putting down plant for preliminary treatment, or anything else, they would rather pay us 2d. per 1,000 gallons for treating their effluent. We have others in our sewers that do not pay; they say they have a prescriptive right, which we are bound to admit. The reading of the law is, once into a sewer and they are always in, but we can keep out those that are out. We have men wanting to enlarge their works and build new works, and we always make them pay, and they do pay, but the difficulty is getting all the manufacturers to agree. I believe if there were some recommendation from your Commission to the Local Government Board that something should be done, and if we could get an Act allowing authorities to charge, that it would solve the whole difficulty. I believe the majority of our manufacturers at least are willing to pay a reasonable charge for their trade effluent, but one man says, "I am not going to pay for my effluent while another man has his treated for nothing." Of course, we do not pay any more than we are absolutely bound to pay; none of us do, and I do not blame the man, but I do think a tribunal like this ought to assist the authorities to solve this problem. We have a dry weather flow of 1,000,000 gallons of domestic sewage—1,250,000 about—with 3,500,000 of trade effluent, which partly goes into the river and partly into our sewers, and the cost of treating our sewage yearly—what we have now, about 2,000,000 gallons—is about £4,000 a year, and we also have sinking fund and interest on £100,000. We have now promised to spend another £58,000, and there is sinking fund and interest to add to that, and we think it only fair that we should be in a position to charge the manufacturers a reasonable amount for treating their effluent. There is another thing; in a thickly-populated place like an industrial centre such as ours, the mills are surrounded by dwelling houses, and if they had to erect works of their own for treatment, it would create a very great nuisance, and we are contemplating doing away with all the little sewage works that we possibly can, and by getting something in an Act of Parliament—a recommendation that manufacturers should pay—we should be able we think to do away with all those petty little works of the manufacturers. Ours is a very bad effluent. We have something which neither Bradford nor Ossett has. We have Fuller's earth for blanket filling and cloth filling, and it is very strong and difficult to deal with. We do not propose to charge every manufacturer alike; what we want the power to charge for, is so that we can charge according to the quality of the effluent.

34157. Yes ?—Some would perhaps pay less than 1d. per 1,000 gallons, while other people whose effluent was strong might have to pay 3d. Our minimum is 1½d., and the maximum 3d., and we draw £200 a year now from manufacturers who have voluntarily signed our agreement. If the manufacturer wishes to, he can give three months' notice to have his charges revised. Our agreements with our manufacturers are such that, if they think we are charging too much, they can give us notice, and we go through the charges and the quality of the effluent, and we may give them a reduction. I do not think local authorities wish this to be put on to make a profit; we do not wish to make a profit, but we do not think it is fair that the general ratepayer, who has no trade effluent, should pay for the treatment of the trade effluent of the manufacturer. Now, most of my figures are in my head, but I may say that the total rates the manufacturers pay in our Borough are £7,000 in round figures. The colliery proprietors, iron-founders, tradesmen and shop-keepers, pay £19,000, and they have no trade effluent. The householders pay £27,000, and three-quarters of our sewage—which we shall no doubt take into the drains on agreement—will be manufacturers' effluent so that the men who will send three-quarters of the sewage only pay about one-eighth of the rates. On our sewage we estimate that, with sinking fund and interest on our new works, and working expenses, it will cost £10,000 a year. That means that in the total rates which the manufacturers pay for the mill premises and dye-houses, they do not pay in their rates what the effluent costs for treating. I do not know that I have anything else to add, only we thought it wise that if you are to issue your final Report—I do not know how we got to know, but we heard you were going to issue a final Report—we should see you and place these facts before you, that you might seriously consider the advisability of recommending the Local Government Board to promote a Bill of some kind to give power to charge, but not to force them to charge. It would be optional, but they want the power.

34158. There is one consideration which applies to all such places. Would it be a severe tax on the manufacturer ? There is a great deal of competition in trade of course. If that sort of thing were done, would it seriously hamper them in any way ?—I do not think it would, because the manufacturers we consider are very wealthy men, and they do very well. Alderman Sir Mark Oldroyd has a firm that is limited, and they have large salaries, and they have paid no less than 7½ per cent. for 15 years.

34159. It is prosperous on the whole ?—I contend that a trade effluent is a trade liability. (*Alderman Johnson.*) I do not think it would affect the woolcombers, so far as Bradford is concerned. (*Alderman Gledhill.*) Most of our manufacturers have risen from working men, or their fathers have done so. Those that are old men and are living were workers themselves, and they appear to keep adding to it. Some of them die and leave £90,000 or £100,000.

34160. There is this point—I do not know whether it is worth mentioning—but the prosperity of the whole district depends on the manufacturers, and they are really paying for the prosperity of the district, and if the manufacture is hampered they will be the ones to suffer by losing work ?—(*Alderman Johnson.*) It would depend on the electors themselves, who would elect the Council and the Sewage Committee, and determine the policy. This is merely a distribution of the burden. Our contention is that certain persons are paying more than they ought to pay, and certain persons are paying less than they ought to pay, and it is merely an adjustment of the burden; and the policy would be dictated by the ratepayers, who would elect the Committee and give them power; and if members of the Committee were elected who were not in favour of making a trade charge, and there was a majority of them, there would not be a trade charge.

34161. It would be taking an exaggerated case, which probably does not occur, but one can imagine the cost of disposal would be so great as to be prohibitive, and it is shared at present by the whole community; but if you threw it all on the manufacturer he might have to shut up his works, and the community would be ruined. Of course, I am stating a merely supposititious case ?—That is all right, but in any case dyers and bleachers—who use a large quantity of water—pump as much water as they can, because they can do it at less cost than they can buy water. The policy of the Council has been dictated in past years by large consumers of water, who have started a scale of charge for water which is actually less than cost price for large consumers. Then it is the small consumer who has had to make up the profit, and if we readjusted the burden it would be different. Then instead of paying, as one man does, £35 in his total rates, when it would cost us £68, it would seem to be reasonable that when he uses 1½ million gallons, that if he only paid 1d. per 1,000 gallons, he should pay £6 instead of £2; and if he paid 2d. per 1,000 it is not an excessive price. We want it to be looked at from the point of view of the trader as well as the ratepayer, and I think this difficulty is peculiar to the West Riding of Yorkshire. Your recommendation that we should charge for a trade effluent would not affect the vast majority of counties. It would not affect Essex, Kent, Somerset, Norfolk, or any of those places. It would only apply to where the difficulty existed. We are not suggesting that we should be placed in a position to make profit out of these people; we are merely suggesting that we should have power to equalise the burden, and make them pay a fair share. (*Alderman Gledhill.*) I do not think it would be a hardship to the manufacturers. The manufacturers appear to go on just the same, some of them getting all their water from wells or from the river. There are other manufacturers who pay 7d. per 1,000 gallons for all the water they use, and they go on with the work just the same, and compete with the others. We have one firm that discharges 600,000 gallons a day; they put into the river what they get out of the river. Now, the firm next to them sends about 50,000 gallons a day, and they buy their water at 7d. a 1,000 gallons, and pay 2d. a 1,000 for putting it into

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the sewers. Those who get it for 1d. a 1,000 gallons will not pay for it to be treated. (*The Mayor of Ossett.*) Would it not put the manufacturers all level ? In Ossett 75 per cent. of our traders are in the sewer, and consequently the Corporation is treating the effluent. What about the other 25 per cent ? They have to treat their own and make it satisfactory to the Rivers Board, and the Rivers Board, as you know, are considerably keener; I do not suggest that they were ever keen, but they are considerably more awake to-day than they used to be. They have to put down plant sufficiently large to satisfy the Rivers Board, and though they have done that, they have to pay the sewage rate like other people, though we get the whole of the effluent treated for no cost at all. During the last two or three years there have been one or two mills built and businesses started in Ossett, and the Council has absolutely refused to take their effluent except under agreement, and that is for a specific charge. The idea is, once in a sewer always in a sewer; you cannot turn them out. Some of these men are paying 1d. and 2d. per 1,000 gallons for treatment of the effluent, and they have to pay the sewage rate. Is it fair as between manufacturer and manufacturer ? We know the Rivers Board in a short time will insist on those manufacturers who are out at the moment putting down a more expensive plant, or turning it into the public sewer for the Corporation to deal with. The Corporation of Ossett will absolutely refuse to take in these manufacturers, except under agreement. We say, if we can have the power to make a charge throughout the length and breadth of the borough which is fair as between manufacturer and manufacturer. and fair as between manufacturer and the general body of ratepayers, it would be much better.

34162. (*Colonel Harding.*) We have listened with much interest to what you have said. You have told us that the incidence of taxation with regard to sewage effluents is very inequitable, and you have certainly given us some startling figures, but I think it is generally assumed that the incidence of rating is inequitable in other directions than that of sewage. You may have a man who makes boilers, and takes huge weights along your roads, and yet pays no more rates than another person who sends light weights along your roads. It is impossible to reach absolute equity in the incidence of taxation, but we appreciate that what you wish is to make the incidence of taxation equitable in regard to sewage effluents. What we want is to find out where we agree, and what it is you specifically propose at the present moment that we should recommend in our report. I take it, Mr. Johnson, you are still of the opinion you were when you gave evidence on a former occasion, that it is desirable in the abstract for traders to be enabled to turn their effluent into the sewers; that it is better for the community to treat with the domestic sewage the sewage of these businesses, than to call upon the individual manufacturer to put up plant in his place, which will not be looked after, to do his own purification ? I take it that in principle you are agreed it is far better to give the trader facilities to get into the sewers ?—Far better.

34163. I notice you are agreed that it is wise to do as Sir William Ramsay suggested—wise in the interests of the trade of the district not to put difficulties in the way of manufacturers, but as far as possible to facilitate the expansion of trade in a district by receiving into your sewers those effluents ?—Yes. (*Alderman Johnson.*) I should like to support that by giving you a case. An attempt has been made in Bradford during the last two years to declare the business of wool-combing and the treatment of bye-products as an offensive trade. In the interests of the trade of the City of Bradford, we resisted it, and I believe all the wool-combing effluent should be taken to our works and dealt with.

34164. In our third Report, after hearing a great deal of evidence both for local authorities and manufacturers, what we then suggested was that generally no set charge should be made on manufacturers for allowing them to bring their effluent into sewers, but that power should be given in special cases—where either the volume was very great, or the quality of the effluent very objectionable, so that it might cause difficulty at the sewage works—power should be given to make a charge.—We suggest to you that the West Riding is a special case.

34165. That was what we recommended, that generally no charge should be made, but that power should be given in specific cases to make charges. What is it you recommend ? Do you recommend that a charge should be made for all trade effluents that go into the sewers ?—(*The Mayor of Ossett.*) That is our recommendation.

34166. Is that, may I ask, quite practicable ? Have you thought it out ? In all large towns there are a multitude of little trickles of effluent, quite small volumes of effluent, which come from a great variety of sources. Do you suggest that in every one of those cases you should make a charge, or would you eliminate all those small quantities, by making a limit that below such and such a volume there should be no charge ? What is your suggestion ? I am trying to get your views ?—(*Alderman Johnson.*) In practice, those with a small effluent which was not difficult to deal with would have admission into the sewer, but our difficulty in the City of Bradford is greater than in Leeds, Sheffield, or Huddersfield. Our difficulties are with the effluent from the woolcombers, and the quantity of effluent from the dyers, and it would work out in practice that the Committee would allow a free admission of the hundred and one little trades we have in Bradford. One of the most offensive trades in Bradford, and one with the smallest quantity of effluent, is sausage-skin washing—an industry carried on, not only for Bradford, but for a very large area. We do not preclude those people, because there is a certain amount of fat in it, and we get it back again. There are a hundred and one trades that would come into the sewer free, but in case we have a large daily volume we want some control to regulate its flow.

34167. There we are going on to another point; it is interesting, but I do not want to deal with it at the moment. What I want to get at is this: I thought at first your proposal was that a charge should be made in every case. I gather now from your explanation that you suggest that all these small flows should not be charged for, but that charges should be made in specific cases ?—That would work out in practice, because the Committee would have to deal with it. The Committee would say to the engineer, "What is the trouble at the works; is it volume, or is it a very bad sewage ?" The engineer would tell you that all our difficulties are with woolcombers' effluent.

34168. We have to look at this thing carefully. You ask us to make certain regulations. I gathered at first that what you were proposing was to make a charge in every case for admission to the sewers of effluent. Now I gather you propose to allow a large number of minor flows of effluent to come in free, and you only propose to make a charge in particular cases, where difficulty is caused by the volume or quality of the effluent put into the sewers. Is that what you propose ?—We say that in special cases the local authority should be entitled to make a charge. We say we have 8,000,000 gallons coming from special cases.

34169. (*Chairman.*) You wish to have the right to make a charge ?—The right.

34170. Whether you make it or not ?—Whether we make it or not is a different thing. I suggest it would be similar to the art gallery power; local authorities have power to raise money for art gallery purposes not exceeding a certain amount. I believe it is 2d. generally, put on ½d. at a time.

34171. (*Colonel Harding.*) I gather from Alderman Gledhill that he considers it a great hardship that, while a new manufacturer, or a manufacturer proposing an extension, is compelled to bargain with the local authority before he is allowed to put his effluent into the sewer, his neighbour turns his effluent into the sewer, and has done for years, without being called upon to bargain or pay anything at all, and that that is quite inequitable. How do you propose to deal with cases where a manufacturer claims he has a prescriptive right to turn into the sewer, having for long periods so turned into it ?—(*The Mayor of Ossett.*) We have provided for that in our Bill.

34172. Would you tell us how you propose to provide for it ?—I can tell you.

34173. (*Mr. Willis.*) You are putting him on the same footing as the man who wants to come in now ?—Quite !

34174. (*Colonel Harding.*) You are to make it retrospective ?—A man who is in at the moment, do you mean ?

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34175. You are asking for powers to charge a man who has for many years been turning into the sewer ?—Exactly !

34176. Are you suggesting that we should recommend legislation to give those powers to all local authorities ?—Exactly ! (*Alderman Johnson.*) Yes, we do. (*The Mayor of Ossett.*) I should like to support that, that the authorities should have the right, and it is a matter for the local authority themselves to say whether a man's effluent is too small to be worthy of consideration. I think that is a matter which could be safely left to the local authority. Give them the power, and if they think it is worth while, they will make a charge. Give them the power to charge everybody; do not exclude anyone; give no authority the power to exclude any trader, but give each authority the power to charge in every case. Whether it is worth their while to charge is another matter, but a matter which ought to be left to the local authority.

34177. Put briefly, what you put before us to-day is this, that every local authority should be given power, if they choose to exercise it, to make a charge for admission of trade effluents into their sewers, and also to compel those who are already connected with the sewers to pay the same charges as are exacted from those who build new works ?—Exactly ! I think there would have to be some restrictions. A man who does partially treat his effluent ought not to be paying as much as the man who is turning his effluent in crude. There might be limitations in the thing.

34178. Do you think it would be quite right for the local authority to take into account that a man has put down a plant for bringing about effective settlement ?—I think the local authority should do it; they ought to be restricted in that.

34179. With regard to what Mr. Johnson said, he thought the decision with regard to the charge should be absolutely left to the local authority, without power of appeal to anyone. I gathered that ?—(*Alderman Johnson.*) I am not very strong on that matter, but my experience is that the Council, which is revised every twelve months on going before the electors, is never unreasonable.

34180. If it were not possible to settle amicably, do you think it would be well to have powers of appeal to the Local Government Board, under present circumstances, or to a new central authority to be established ?—I do not object at all. I do not think the power would be exercised.

34181. You think it would be right to have some power of appeal ?—I do not object at all.

34182. Would the basis of charge be the cost of treating the sewage ?—A part of the cost.

34183. Take a simple instance which you have mentioned. A man who turns 1½ million gallons into the sewer is rated at £35 ?—Yes.

34184. Your proportion of that sum would be only £2, and the cost of treating that effluent is £68 ?—Yes.

34185. Would you propose to charge him £68 ?—Certainly.

34186. What then ?—I think we ought to have 25 per cent. of the cost; that would be a reasonable thing. my own view of the matter is that we should not exceed 3d. per 1,000 gallons for the woolcombers.

34187. Threepence per 1,000 gallons would bring the cost to this man to what ?—A quarter of £68 ; that would be £17.

34188. Why do you not propose to charge him with the cost ? Do you think the £68 would be prohibitive to his business ?—Not at all.

34189. I think you have one case where the cost would be about £600 to the manufacturer if he treated it himself, and it cost him the same as it would cost you ?—He gives us 163,000,000 gallons, and the total rate is £1,418. Our proportion is £66, and if he had to treat it himself, and it only cost 1d. per 1,000, it would cost £680.

34190. Surely that is greatly below the cost ?—Yes. I suggest he could reasonably pay a quarter of £680 for his 163,000,000 gallons per annum.

34191. I am not quite clear about that. You say £680 ; is that the cost of treating that volume of effluent ?—It would be the cost if we gave it a final treatment. We do not give that final treatment, but, if we did, it would cost us £680.

34192. At 1d. per 1,000 gallons. What would it cost him ?—It would cost him £680.

34193. That is at 1d. per 1,000 gallons ?—Yes, and we get £66 towards it.

34194. What is the nature of the charge you propose to make ? Is it a charge to cover the cost ? I gather now you suggest a quarter of the cost. What would be the basis ?—It would be difficult to work out a basis, because you must remember a mill owner pays a sanitary rate to have certain sanitary conveniences, but I say this man is getting an excess of treatment. He is entitled to something, and he is entitled to consideration in a matter of that kind.

34195. Then you do not think it would be advisable to suggest that the basis for the charge should be the cost of the treatment, but that you would prefer that the charge to be made should be left absolutely in the discretion of the local authority, so far as they are able to agree with the manufacturer; and, failing agreement, that it should be referred to the arbitration of some central body ?—Yes.

34196. You think it would be better not to lay down that the cost of treatment is to be the basis ?

34197. That would be an excessive charge ?—It might be.

34198. And it would be an absolute injury to trade ?—I do not think it would be an injury to this trade to pay £500 for the treatment of 163,000,000 gallons per annum.

34199. But you prefer that no basis of charge should be indicated ?—Unless you like to say "not exceeding a certain amount."

34200. Is it desirable to go so far ?—I do not think it is. I think, if it is left to the local authority, they and the trader would come to an agreement, if the local authority had power. I think I could come to an arrangement with the manufacturers in Bradford inside a month, because they would know we had the power behind us. Now they say, "Where is your power ?"

34201. The important thing you want to accomplish is to have power to deal with those cases which are already connected with the sewers, and make them pay ?—Yes.

34202. At present you have the power to deal with the man who is proposing to put an effluent into the sewer ?—We have.

34203. The power you want is a retrospective power to deal with those who are already in ?—That is it. (*The Mayor of Ossett.*) Exactly ! (*Alderman Johnson.*) There is a great difference between that and what I have taken to be the attitude of the Royal Commission. The Royal Commission would personally give the manufacturer the right to go into the sewer; we do not oppose the manufacturer having that right, if we have the right to get something towards the cost of treatment. In Bradford we do charge new firms, and we get prices from 1d. to 8d. per 1,000 gallons. We get the raw wool combers effluent and charge 8d. a thousand, but it does not bring in much money. (*Alderman Gledhill.*) We have no reason to charge in our district; the manufacturers take all out of the effluent that is valuable. (*Alderman Johnson.*) That is what they do with the wool combers. (*The Mayor of Ossett.*) Where it is possible they recover.

34204. (*Mr. Willis.*) I think you said that in 1897 you tried to get power to over-ride this prescriptive right and failed ?—(*Alderman Johnson.*) In 1897 we went to Parliament with a Bill to make a separate sewer for the wool combers. We were advised by Professor Dewar that our best method of treating the sewage was to separate the wool washing from the ordinary domestic sewage. We went for the powers, and we were opposed by the traders, and that part of the Bill had to be dropped. They gave us an agreed clause that certain persons had a prescriptive right, and if we paid them £18 per comb we could then charge them for going into the sewers, but if they had not reasonable and available means for the treatment of their effluent, that we could not charge them. They have set up the plea that they had not reasonable and available means for the treatment, that it was too expensive to acquire land, and they preferred

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to extend their works rather than extend the disposal works, and those traders we have not power over.

34205. I rather gathered that you went in 1897 to Parliament in a view to over-riding those prescriptive rights. I think the Commission said in their third Report that they thought everybody should be put on the same level, whether now discharging or not, but I gathered from you that you had gone to Parliament with a view to overriding those rights which certain people had acquired, and that Parliament would not give it to you ?—With the wool combers only.

34206. Supposing a general Bill were brought in, in which it was proposed to charge everybody, do you think there would be considerable opposition to such a Bill on the part of the manufacturers who now discharge into the sewer ?—Yes. (*The Mayor of Ossett.*) I have an idea that some local authorities would oppose you vigorously. I do, in fact, know that some Corporations will oppose vigorously for this reason; they have not the manufacturers in the sewer at the moment, and they do not want them in, on terms even. They fear, and legitimately so, that if they take the manufacturers in it means a tremendous capital expenditure, which they are not prepared to make at the moment.

34207. Of course, in the recommendations which the Sewage Commission made, although they said it should be the general rule that a manufacturer should have a right to discharge into a sewer, they have also advised that there should be an appeal in any case where the local authority considered it undesirable that the manufacturers for any reason should go in. There was that buffer always ?—(*Alderman Johnson.*) May I follow that for a moment. Supposing the recommendation is adopted that all the manufacturers in Bradford should go in, and we object, whom have we to appeal to ? Are we to appeal to the Local Government Board ?

34208. Under the recommendation of the Sewage Commission, you would appeal to the central authority. I am surprised to hear there is likely to be strong opposition on the part of local authorities to altering the law.—(*The Mayor of Ossett.*) Wolverhampton will be one. If I may tell you, I have been before the Law Committee of the Municipal Corporations Association.

34209. I know they have been considering it.—As a matter of fact, one or two there said that, even if the Municipal Corporations themselves proposed a Bill or presented a Bill, they would oppose it; they would block the Bill, and even if the Government presented a Bill they would make it impossible.

34210. I do not know about that.—That is the statement to me.

34211. (*Colonel Harding.*) Their object is not to make a charge on admitting them to the sewers ?—That is it; they do not want it.

34212. (*Mr. Willis.*) But do you not gather that most local authorities who have manufacturers in their district would welcome a law ?—Yes.

34213. You will always find exceptional people standing out.—If you take our district—the West Riding of Yorkshire—every Council is unanimous on this point. We have had two conferences of local authorities; we called two which were held in Ossett Town Hall, and they were unanimous. As a matter of fact, the idea in the first instance was to promote a joint Bill on this matter, but there was no precedent for such a thing, and it dropped through on that account; but it was so acute in many towns that we have taken the bull by the horns and are going on our own.

34214. Do you think the number of local authorities who would oppose such an alteration in the law would be comparatively small ?—Very small indeed. You could count them probably on one hand, and they would be very large Corporations. Morley had power last year, and Huddersfield and Halifax and Heckmondwike have power.

34215. Speaking generally, do you think most large local authorities would oppose an alteration in the law ?—In my opinion, more than 90 per cent. of the Corporations would strongly support it; more than that.

34216. Going on to the question of charge, do you think a very large number of manufacturers who are now putting effluent into the sewers without payment would organise an opposition to a measure which gave the local authority the right to charge ? Would that be a serious opposition ?—With regard to my own town, the evidence is that they would not oppose it; they recognise that it is only fair. As a matter of fact, a few of our larger manufacturers are supporting our Bill at the moment.

34217. (*Colonel Harding.*) Manufacturers who are now connected with the sewers ?—Yes, who are now connected with the sewers; and those who are not connected, but are fearing they will have to come in at a later period, are enthusiastically supporting the Bill.

34218. (*Mr. Willis.*) I suppose you would agree on the question of charge that manufacturers in the same class of business in the same town should pay the same rate ?—(*Alderman Johnson.*) Yes.

34219. You should not have an opportunity of allowing jobbery ?—(*The Mayor of Ossett.*) That is provided for in our Bill.

34220. And you attach importance to securing that ?—Exactly !

34221. And if there are two dyers, one in at a certain rate and another in at a higher rate, you would give either dyer a right to appeal to the Corporation first, and then to the central authority if necessary to secure equality ?—Exactly. (*Alderman Johnson.*) The same as the water charge. Every person taking 400,000 gallons in Bradford gets it at 9d.; everybody taking above that gets it at 7½d. We do not sell it a farthing less to dyers because they take so much a day.

34222. Do you think it is desirable to provide machinery by which one town would be prevented from competing with another ? Supposing Bradford said, "We want to attract the woolcombers, and we will let them put in their refuse for nothing."—No Act of Parliament would attract them to Bradford, because the market attracts them.

34223. You can conceive of two towns, both of which would be suitable for some trade; and one town might say, "We are going to encourage these people and not make a charge." Their neighbours might object to that and say, "We are going to make a charge, but at the same time we feel our neighbour is going to unfairly compete with us; they are taking the stuff for nothing." Do you think some arrangement should be made to prevent competition between towns ?—I do not think it is likely to happen. Supposing Leeds said, "We will take woolcombers effluent into our sewer for nothing," and Bradford charged 3d., they could not remove the wool trade from Bradford.

34224. I agree, but it is a general question. There are trades which could be carried on in Bradford or Leeds ?—We could not get the machinery trade from Leeds if we gave them rates free. It is the centre, and if we said, "You shall have this place for ten years without rates," we could not get them.

34225. Batley and Dewsbury; are they adjoining towns ?—We call them one.

34226. Have they similar trades ?—Yes.

34227. One town might be adopting a different policy on this question.—(*The Mayor of Ossett.*) I can see the possibility in Dewsbury and Ossett, where we are engaged in similar trades, and I should not object to some machinery. I think it is very unlikely though. (*Alderman Gledhill.*) We have had that to deal with. When we sent to our manufacturers about their effluent, Mr. H—— said, "I will remove to M——." "Very well," we said, "you can remove to M——." He bought a mill at M——, but he sold it and came back again. I do not think that would make any difference. (*Alderman Johnson.*) I do not object to the power, but I do not think it would be used. (*Alderman Gledhill.*) Where a man has his workmen, if he gets good work done, it pays him to stay. He will not leave for the sake of the effluent.

34228. My question was based on something which Mr. Johnson said. He said he thought the electors should decide the policy in each town. They will generally do it, and I quite agree. I was wondering whether it was desirable to provide some safeguard to stop unfair competition between towns, giving, say, Dewsbury the right

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to appeal to the central authority against the policy which Ossett was adopting, or vice versa.—The man I mentioned who removed to M——, several miles away, could not get the class of men he had at Dewsbury, and he came back to his old mill.

34229. (*Chairman.*) We are very much obliged to you for giving us your views.—(*The Mayor of Ossett.*) I have a few copies of the statement I alluded to, and I will leave them with you, if you wish. There is the statement of the Ossett case in figures.

ONE HUNDRED AND SEVENTH DAY.

Friday, 3rd July, 1914.

PRESENT :

Sir William Ramsay, K.C.B., F.R.S. (*in the Chair*).
Colonel T. W. Harding, J.P., D.L.
Sir Thomas Stafford, Bart., C.B., F.R.C.S.I.
Mr. R. A. Tatton, M.Inst.C.E.
Mr. R. H. H. Keenlyside (*Secretary.*)

ALSO PRESENT :

Dr. George McGowan.
Mr. C. C. Frye.
Mr. G. B. Kershaw.

Dr. G. Herbert Fowler, Member of the Bedford County Council, formerly Member of Ampthill Rural District Council, called in; and Examined.

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34230. (*Chairman.*) I had better begin with the usual questions, Dr. Fowler. You are living at Aspley Guise ?—Yes.

34231. In the Old House there ?—Yes.

34232. You were formerly in the Biological Department at University College ?—Yes.

34233. You have had a training in biology and you still work at it ; is that so ?—Yes.

34234. You have sent us in a document here which I think, if my colleagues agree, we will take as read and print in our Report :

It was suggested to me that the Royal Commission on Sewage Disposal would wish to hear something of the actual working of a scheme of water-borne sewage in a rural area. The point which I wish to make is that the present methods of the Local Government Board in forcing such a system on a rural area can produce great financial hardship, unnecessarily, and without corresponding benefit. I take the case of my own parish, Aspley Guise. In order to parry the possible objection—that the health of a district cannot be too dearly bought—it will be advisable to set out the circumstances in some detail, and to show that a water-borne system was not needed.

Aspley Guise, with a population of some 1,300, lies on the edge of the Lower Greensand hills, of West Bedfordshire. With the exception of about four houses served by the sewer (which lie on the outcrop of the clay), it lies entirely on Greensand (in places 100 feet thick) ; that is to say, on a perfect natural filter-bed. A beautiful soft water is plentiful throughout the area over the subjacent Oxford clay. Here, as nearly all over England, Local Authorities permitted the house-speculator to build cottages and houses of the villa type with insufficient curtilage, and to provide them with water-closets and a cess-pit, the latter either having no outflow, or an outflow to land surface drainage. Naturally, a mere chemical analysis of many wells showed high nitrogen values, but even then I question whether a bacteriological analysis would have shewn warm-blood pathogenic bacteria. At the time of the Local Government Board Inquiry, I had such an analysis made, of water taken deliberately from a well near the bottom of the drainage area ; this showed no trace of such organisms as *coli communis*. The conditions at Aspley Guise were, I contend, therefore, such as could have been easily and cheaply reformed by handling the cess-pit question firmly, and by cleaning and disinfecting the wells.

Aspley Heath, also in Bedfordshire, lies entirely on the Greensand, and mainly contains largish houses with extensive grounds. As regards water and sewage disposal, it stood on the same footing as Aspley Guise.

Woburn Sands, a contiguous parish in Buckinghamshire was in a much less healthy condition. Houses with little curtilage had been allowed to grow up in terraces ; a number of these lay on or below the outcrop of the clay ; this implied shallow wells, and their almost unavoidable pollution. I understand that strong measures were necessary in this case. But in order to deal with a case which seemed to require a sewage and water scheme, the other two places which did not need it were, so far as I can see, sacrificed financially for its benefit.

The ball seems to have been started in 1899, when a considerable epidemic of diphtheria appeared all over England ; and some fifty inhabitants of Woburn Sands addressed the Local Government Board in favour of a sewage (not water) scheme. A Local Government Board Inquiry was held in 1905, another in 1908 ; after the latter, the schemes for water and sewerage at present in operation were passed, were extended to include the two Aspleys, and were forthwith carried out.

In order to prevent too heavy a financial burden being laid on a rural area, the Public Health Act laid down that the total loans outstanding on a parish might never exceed the two years' assessable value. The subsequent history of the scheme is instructive as showing how this excellent provision can be evaded. At the 1908 Inquiry, the share of the total estimate debited to Aspley Guise was £10,222 ; there was already an outstanding loan of £495, making a total indebtedness of £10,717. But a two years' assessable value was only £10,592, a fact which ought to have blocked the scheme. This was got round : (1) By omitting a part of the proposed sewer from houses which still remain unsewered ; (2) by including a newly-built house (also still unsewered) which had not yet come into assessment ; (3) by making no allowance for empty houses, then assessed at £150 ; (4) by estimating "Contingencies" at only £300 (the contractor eventually claimed £2,860 and got £689) ; (5) by allowing no provision for wayleaves and compensation claims (they came to over £2,220) ; (6) by leaving such a necessity as an adequate coal store, and many minor matters, to be provided after the works were supposed to have been handed over in going order. Consequently (5) and (6) and part of (4) have had to be paid out of income, as well as heavy preliminary expenses for engineer and contractor in sinking trial wells ; the charges of the solicitor who acted as clerk have not been paid yet. As a natural consequence of estimates having been pared down to the minimum, the materials and work put underground received the severest criticism of those who watched their progress—the work above ground has already needed considerable repair—I have no hesitation in stigmatising the whole transaction as a flagrant evasion of the intended protection of the Public Health Act, which the Local Government Board should have considered and prevented.

The accounts of the three parishes and two counties concerned are so entangled that it would be nearly impossible to find out by how much the two years' assessable value has been exceeded in each case, but it must amount to a large sum; nor can the total cost be ascertained. But as to the results the rates in Aspley Guise for 1911 came to 8s. 5d., of which 3s. 10d., were a special rate for these schemes; for 1912, 10s. 5d., of which 5s. formed the special rate; for 1913, 8s. 2d., of which 2s. 9d. was the special rate. This is not likely now to go lower, for while the interest on loan will diminish, the cost of repairs will increase. Against this must be set a small scavenging rate, which has ceased, but seems likely to be partly renewed in the immediate future. What it has cost tenants and property owners to connect the sewers and water mains, one cannot even estimate. But the deplorable result is, that, so far as I can ascertain, the rents of cottages have been raised by ninepence to a shilling per week. I need hardly emphasise the seriousness of this to mechanics and labourers.

In spite of the cost, it must be admitted that the expenditure would have been amply justified if the health conditions of Aspley Guise had been bad. In 1907 Sir George Newman, then County Medical Officer of Health, made a special report which showed: (1) The almost entire absence of water-borne disease; (2) a normal general death-rate; (3) a very low zymotic death-rate; (4) no abnormal epidemic diarrhœa or diphtheria. Sir George rightly pointed out that there were several houses, especially of the villa type, in an unsatisfactory position as to sewage disposal, but I contend that they could have been dealt with by a less drastic method than one which involved a total expenditure of well over £12,000. It would have been cheaper to buy the houses and pull them down.

The scheme was forced on the inhabitants against their wishes; a poll was taken by the Parish Council of Aspley Guise in 1907, and showed only 10·7 per cent. in favour of the water scheme, 11·1 per cent. in favour of sewage. Only 1·2 had no well or pump, only 4·3 stated that they had not a sufficient supply of good water.

The chief fault, so far as I can see, lies in the fact that the Local Government Board does not sufficiently protect the rural areas. Rural District Councils are composed neither of engineers nor financiers; they rarely seem to include medical men; they tend naturally to accept the lowest estimate, without the skill to see where the reduction has been made. They are clay in the hands of the consulting engineer, to whose interest it is to draft the largest scheme which can be crushed within the four corners of the Public Health Act. I cannot but think that when complaint has been raised of the sanitary condition of a parish, the Local Government Board should in the first place send down their own representative, who should be rather a general sanitary expert than an engineer, not to hold a public inquiry, but to observe and report on the general conditions; and to recommend in outline what kind of measures (by no means necessarily a water-borne system) should be adopted for their improvement. The Local Government Board should then remit the case, unbiassed by interested advice, to the Rural District Council; this could *then* proceed as under the present system.

The Commission will have heard expert evidence enough on methods of Sewage Disposal; but I venture to make one or two suggestions. We still need, I believe, experiment in continuation of the work of the late Dr. Vivian Poore, as to the best method of disposing of the fluids of a house—sink waste, bath water, and urine—on certain soils; notably on a clay soil, where the gradients are usually slight. This seems to be a case for State-aided experiment. The general education of householders, of Rural District Councils, of sanitary inspectors, and even of medical men, as to proper forms of earth closet, their proper manipulation, and their manurial and sanitary value, is sadly lacking. Rural District Councils should be instructed to discourage the installation of water-closets and cess-pits in purely rural areas, and to relax their bye-laws so as to admit of proper earth closets (not pail-closets) in connection with dwellings. Where cess-pits are already in use, the Rural District Council could organise their due emptying for the whole district by a tank motor with motor pump and suction hose at the owner's cost. Where cess-pits are unavoidable, they should be built far more solidly than at present, and no overflow be permitted, least of all into land drainage.

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34235. We shall now amplify this statement by putting questions to you. You point out that the Local Government Board, by forcing a water-borne sewage system on a rural area, can produce great financial hardship unnecessarily and without corresponding benefit; and then you go on to tell the story of Aspley Guise, the kind of its population, its situation, and its being overrun by the house speculator. I fancy one might ask whether the rates have gone up very largely?—Very largely indeed.

34236. Is that owing to the population having left the District?—I believe a certain number have left on account of the rates, but the amount of unlet property is about the same.

34237. My recollection is that there were a great many houses to let?—There are a good many.

34238. Does that affect the working class population? —No it would not directly affect those who compound.

34239. There is no large working class population at Aspley Guise?—Oh, yes, excuse me, considerable. A builder employs about sixty men and printing works employ about sixty men and girls.

34240. Then the rates for their houses or lodgings have gone up?—Yes. In cases where rates are compounded for it would not affect the working classes directly.

34241. Can you tell from your own experience whether the working classes are leaving the district?—No; in many cases they have left their houses when the additional rent was put on by the landlord. It comes round to that eventually; it is bound to, but it does not directly come upon them; and in many cases they have changed their houses and gone into an inferior house, because it was at a little lower rent.

34242. You speak of the cess-pit question. Do you think that a cess-pit is the best way of disposing of raw sewage?—I should say the worst.

34243. What are your views on that subject?—Well, my views are those which I have learned from the late Dr. Vivian Poore, that earth disposal, wherever possible, is the only wholesome and sensible way of disposing of human excrement.

34244. Had you a cess-pit before?—I found one there.

34245. And had you to get it cleaned out periodically? —I had to get it cleaned out once a year. I proposed, as soon as I took my house, to put in earth closets. I was at once met by the local bye-laws preventing any cess-pit being erected within six feet of the house, and as I could not turn women out on rainy or snowy nights, I was forced to relay all my sanitary arrangements and continue the cess-pit and water closet.

34246. One is forced to do that?—One is forced to do that.

34247. Did your cess-pit give you any trouble?—Beyond that of having to be emptied once a year, I do not think it did. It had an overflow, as these things so often do, into land drainage so that practically it was poisoning the water all the way down to King's Lynn, the whole length of the Ouse.

34248. Your garden is on a slope, if I remember rightly? —Yes.

34249. And your cess-pit is not far from your house?— No.

34250. At the foot of your garden you have something in the nature of a small sump or a ditch or a pond?—A series of ponds, and the overflow from all the house

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eventually found its way into that series of ponds, which is part of the drainage system of the Ouse.

34251. Does it still ?—No, because the cess-pits are all shut up; we have now this sewerage scheme.

34252. What becomes of the sewage ? Does it go to a sewage farm ?—That goes to a sewage farm on the principle of depositing beds to begin with. The fluid eventually runs off over little weirs on to a clinker or coke bed. I am afraid I do not quite know the technical terms; you know them better than I do. There is a revolving arm sprinkler out of which the fluid comes and without any further treatment it goes into the land drainage, and of course in the case of a very heavy rainfall the water coming down, the thing simply floods over and raw untreated sewage, not even deposited sewage, goes into the drainage.

34253. Is this place at some distance from the village ?—Yes.

34254. The other town, Woburn Sands, is a fairly large town, is it not ?—It has about 1,500 inhabitants.

34255. Is the purification plant on the road to Woburn Sands ? The system connects all those places, does it not ?—It is rather the apex of a triangle of which Woburn Sands and Aspley Guise are the two ends of the base.

34256. Do you think it is satisfactory as far as it goes from a sanitary point of view ?—Well, I have very grave doubts about the effluent. I have never dared to have what I should like to have, a bacteriological analysis made of the water that comes off that farm, because I dare not contemplate what we should probably find.

34257. In your Memorandum you point out that there has been some loose practice in stating the cost of the proposed Drainage Scheme. Are those statements provable ?—I think they are all provable. I have endeavoured to get the facts from County Council papers and the reports in the local papers of the Inquiry; I have taken my figures from those two and from the Clerk of the District Council who has given me the actual moneys expended. The estimates given at the Inquiry, of course, I have had to take from the reports in the local paper.

34258. For instance, No. 5 in this statement. You state, "By allowing no provision for wayleaves and compensation claims (they came to over £2,220)." Would those naturally come into the rates or would they be excluded ? I mean, the law says—the Public Health Act lays down that the total loans outstanding of a parish should never exceed two years of its assessable value. Would this £2,200 be in addition to that; would it put the action of the Local Government Board within the law ? Perhaps I have not made it quite clear—but would the cost of provision for wayleaves be counted as the expense of the undertaking ?—Surely ! I do not know what the practice of the Local Government Board is, but a plain man would think it ought to be part of the undertaking.

34259. And the expense ?—Surely !

34260. So it comes to this, that practically £2,000 were spent, more than two years' revenue ?—Excuse me; I think I said the claims came to over £2,220. I may say personally I went round and saw a great number of the claimants, and I managed to reduce them by about £1,000; but that, I think, does not touch the point.

34261. No ?—I have not the actual figures of what we are paying; some of them were paid down at once, and some are being paid off on a twenty years' basis; that is an arrangement between the District Council and the claimants, simply because we had not the money to meet it.

34262. I think the whole of this examination naturally would divide itself into two heads: First of all, whether the Local Government Board has done an illegal act in sanctioning such a loan; and second, the total to be expended, as to whether the method of disposal is better or worse than the one which you recommend for country districts. Supposing we examine the first of these at present; do you think it would be possible to show the Local Government Board that it is exceeding its powers ?—I suppose the Inspector was assured at the time that the thing would not exceed the sum which was laid down, the two years' assessable value; but I myself asked at the Inquiry what allowance was made for contingencies—I was there and took more or less an extensive part—I was told £300 would be ample, but you see from the figures I have given here, we have estimated contingencies, £300; the contractor eventually claimed £2,860 and got £689. These figures I have from the Clerk of the Council, so they are undoubtedly accurate. No provision was made for wayleaves—I have the list here for the actual £2,220, but I do not suppose it is to anybody's interest to see how it is divided, but I have the actual claims.

34263. I am not quite sure what happens in a case of that kind, where the County Council exceeds its powers, or where the Local Government Board exceeds its powers. I fancy the Public Accountant revises the figures, and if they are illegal, the persons who have spent the money are personally responsible for it; do you know ?—The Auditor may, of course, surcharge any unauthorised payment by a District Council, but I am afraid in this case the payments were authorised by the Local Government Board. You see they have taken it out of his hands; the scheme had gone through; the scheme is passed.

34264. The question is, is there any redress against the Local Government Board if they have done an illegal act ?—I imagine not, but my object in giving my evidence is to protect any other unfortunate villages.

34265. Oh; quite; if it were possible to recover, it would make a standing example of it, and people would be very grateful in future ?—I should think it is impossible, because the only recovery that the Auditor can do, is to make the man who signed the cheque pay the money, if he surcharges. My point rather is this, that these things have had to be paid, and we have paid them out of income, out of an extra rate, instead of out of the capital fund, which you are allowed by law. That is how they have evaded the two years' assessable value.

34266. You state very positively, "I have no hesitation in stigmatising the whole transaction as a flagrant evasion of the intended protection of the Public Health Act which the Local Government Board should have considered and prevented" ?—That is my opinion.

34267. That is a very strong criticism ?—A considered opinion.

34268. And, you think, quite justifiable ?—You say, the "total cost" means the total cost in each parish ? Of course, the total cost of the scheme can be easily got at; it is the division that is so extraordinarily difficult.

34269. The cost to each parish ?—Then, I may add, the current half-year rate is 4s. 4d., of which 1s. 6d. is for the special rate for water and sewerage.

34270. That is going down ?—No; that is going up again; it is only half-yearly, and the others are yearly. That would come with the other statements of previous rates.

34271. The figures are—— ?—4s. 4d. for the current half-year, of which 1s. 6d. is for the special rate.

34272. Then you remark on the raising of the rents of local cottages ?—That seems to me to be the most serious matter; 9d. a week is a very serious matter for a working man.

34273. You also remark, in concluding this part of your evidence, that the scheme was forced on the inhabitants against their wishes. Does that imply Aspley Guise alone or the whole of the inhabitants ?—That implies, I think, the whole of the inhabitants; I only have the figures for Aspley Guise, I have only the actual paper issued and returned for Aspley Guise. I think my figures are only for Aspley Guise; the percentages of people who were against it.

34274. In Woburn Sands the proportion was about the same ?—Yes; the proportion was about the same.

34275. So that practically there was a majority of the inhabitants against it ?—Oh; a very large majority.

34276. You make certain recommendations; that the representative should rather be a general sanitary expert than an engineer, who should observe and report on the general conditions; and recommend what kind of measures should be adopted for their improvement. The

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Local Government Board should then remit the case, unbiassed by interested advice, to the Rural District Council; this could then proceed as under the present system. I think that is a very sensible course, is it not; their usual practice I do not know?—The usual practice apparently is that the scheme is produced; the Local Government Board then sends its Inspector, who decides for or against the scheme. But what I should like to suggest the Local Government Board ought to do is to try to protect the villages against the engineer; that is really what we want, to see whether it is not possible for some other scheme to put the place on a sanitary footing, and, if possible, not a water-borne scheme.

34277. Are the houses in Aspley Guise close together—I do not remember any terraces?—Not in Aspley Guise as a rule. Of course, Woburn Sands is on an entirely different footing geologically, and also in the way the place is built. One quite recognises that something serious had to be done there.

34278. Would it facilitate matters to have had some sort of collecting arrangement; something in the nature of dry closets?—That would have been perfectly feasible.

34279. It is not a very large proposition; there are not very many houses?—No. Such a scheme had been put into operation for about a year and a half—I forget the exact time; quite a short period—when it was all swept away before this scheme, and it was working quite satisfactorily. As Dr. Newman remarks in his Report—I forget whether he was the County or Local Medical Officer of Health; one of them—he was quite satisfied with the way the thing was going.

34280. I suppose the houses have back-yards?—Most of them have; some only quite in the centre of the village have them, merely back-yards; not perhaps in some eight houses.

34281. There was no difficulty of access to the back-yards, or wherever the stuff had to be taken away from?—No; not in any case that I know of.

34282. So it is a comparatively small thing; there are not a large number of those houses?—No. Of course, what as a rule happened, I think, was that the men who had allotments simply took the stuff out and took it into their allotments, which is exactly what we wanted.

34283. That is what we want done, exactly. Are there wells near those houses?—Oh, yes, but the wells were undoubtedly polluted.

34284. Are they surface wells or deep wells?—They have to go down to the Oxford Clay wherever it is practicable.

34285. Does that mean much?—It means in some places more than 100 feet, and in other places perhaps 10; but it is more likely to be 100 feet than 10.

34286. Had each house its well?—Very nearly.

34287. But there could have been a combined arrangement for well water, I suppose, without much trouble?—Oh; quite easily, and if the cess-pits had only been shut and the walls cleaned it would have been perfectly right, we should not have required a Water Scheme at all.

34288. Where does the water come from?—I suppose it is simply the rain that soaks down.

34289. I do not mean that; where does the new water come from?—From the next valley, I might call it; the valley of the next brook, the other side of a little hill, where it is pumped again from the bottom of the Greensand.

34290. There are wells there?—There is one big well sunk for the purpose. I think there they have gone down something like 130 feet. It is beautiful water—so was the other, of course, when it was not polluted.

34291. But you think a common water scheme might have been introduced, which would not have carried with it this method of disposal of sewage—there is no need to combine the two?—There is no need to combine the two.

34292. Your expression, "handling the cess-pit question firmly"; I suppose that involves shutting up the cess-pits and putting in dry closets?—It provides, in the first place, that they shall have no leakage; if they are to remain they must be absolutely tight. As it is, of course, I am afraid, in many cases—I cannot speak from my own knowledge, but I have understood—they have simply built the walls of the cess-pit, and nothing on the floor, simply allowed the stuff to soak away and periodically dug out the solid matter which remained. I cannot speak of that from my own knowledge, but I think a very large number, probably half of those which had been built, had an overflow into land drainage, with most disastrous results on the brooks.

34293. They simply fill up the surface?—Yes.

34294. Was there a satisfactory scheme for cleaning the cess-pits?—No; each man did his own; there was no control whatever.

34295. I do not know whether it is generally known, but I have been asking questions on this part of the subject lately; in many parts of the country I found they build cess-pits to conform to regulations, and as soon as the Inspector has gone, they break them up. It is a universal habit, and it is as well that it should be known; there is no penalty, and nobody knows; it is the universal habit. I am not sure that it is a bad one, because it simply means that you have got a land drainage. It depends on whether there are wells in the neighbourhood which can be polluted; but that is the universal system where cess-pits are employed.

34296. Do you know who conducted the Local Government Board Inquiry in 1905?—No; I know only about the last one; I was not down at the earlier period.

34297. Did you see the official they sent down?—At the last Inquiry?

34298. At the one in 1905?—No; I was still living in London.

34299. In 1908?—In 1908 I was there.

34300. Did you see the official?—Yes.

34301. Was he an engineer?—Yes.

34302. Was it to his interest—it could not possibly be to his interest—to make a Scheme; was it?—Oh! I do not suggest it for a moment; except in this respect, of course, that engineers do all hang together in a most extraordinary way; if one engineer can give another a job, he will. Excuse me asking a question; Is it not rather the attitude of mind of the Local Government Board that a water-borne scheme is the one and only possible scheme? I think they start with that predisposition.

34303. Yes; I am afraid they do, because they are used to towns. You have read Dr. Poore's "Rural Hygiene"?—Yes.

34304. And you agree with what he states there?—Certainly.

34305. And you would, if you could, have adopted that scheme for your own place, if you had been allowed?—Yes.

34306. It appears to me it is our duty to recommend that scheme very strongly for all country places where it is possible to dispose of sewage?—The point which Dr. Poore left unsettled really was the disposal of fluids on a clay soil. That does present difficulties.

34307. It seems to me bath water is one of the main troubles; You require double drainage; it should not go into the cess-pit and to get rid of it in the garden or somehow or other is not easy. Have you any suggestion to make in regard to bath water?—I think not. The only suggestion I have to make is that it is good enough for a State aided experiment. Dr. Vivian Poore found the greatest difficulty would be in a flat clay soil where there was much fluid. Turn it into a field to drain, and it will do no harm to anybody.

34308. That is so. My recollection is that he filtered kitchen refuse through straw and found that the straw did not become putrid?—Sawdust he tried also.

34309. Sawdust he tried also for urine chiefly?—Yes.

34310. As to the trouble about urine you could have 3 to 5 per cent. of urea spread on the garden and adopt his plan of watering part of the soil with urine in order to encourage the growth of organisms there dealing with the excreta in another way altogether?—That means a certain amount of difficulty in the construction of the earth closet I fancy, keeping the fluids and the solids separate.

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34311. You must remember people do not always use their closets for micturiation; a large amount of the urine is disposed of otherwise. Have you any experience of earth closets?—Oh yes.

34312. Quite satisfactory?—Quite satisfactory. They require a little care, more care than water closets.

34313. There is no difficulty in getting people to clear them?—No.

34314. They are not costly?—They are not costly.

34315. It there any difficulty in getting the gardener to use the stuff?—I think in most cases he would be very glad of it, extremely glad of it. On a clay soil it tends to bind the ground too much I am told. The clay soil I think is the sole difficulty. On limestone, sand or chalk as far as I can make out there is nothing better than the earth closet. It is a question whether it can be properly utilised on a clay soil.

34316. (*Colonel Harding.*) I would just ask Dr. Fowler one or two questions, not so much relating to Aspley Guise as to the general questions of rural sewage disposal. I gather that you, Dr. Fowler, like Dr. Poore, favour the earth-closet wherever it is possible in small communities?—Yes.

34317. But are we not obliged to consider the intimate relation of water supply with sewage disposal even in the case of quite small communities. For instance, if you have a very small water supply, the domestic water will not be abundant, and can possibly in this case be dealt with on the garden. In many cases I daresay they take it out in buckets and pour it out on some part or other of the garden, and then the earth-closet deals with the other matters; but the moment you get an abundant water supply, and I notice you mention in your own case there is a beautiful and plentiful supply of water, the difficulties become at once greater, do they not?—Because people use more water.

34318. They use considerably more water?—Yes.

34319. Therefore the arrangement of having earth-closets, disposing of the domestic water on the garden presupposes first of all that there is a garden on which to dispose of it, and, secondly, that the water supply is a very small one?—I am not quite sure that I see the second point.

34320. Well, in this way: If the water supply is only a small one, if it is raised, for instance, by pumping, people do not take the trouble of pumping abundant water even if it exists. The pumping of water leads to labour, and people are economical of labour, and therefore the amount of water used per head is small. But if you have a pipe supply with abundant water reservoir and people can simply fill their buckets from taps, they use a great deal more, and the moment they use a larger quantity of water your difficulty is at any rate increased; you can no longer pour the odd bucketful over the garden, but you must lead it into some sort of receptacle, must you not?—You are discussing really the question of a water supply without a sewage scheme.

34321. It seems to me the two are intimately associated, and that Dr. Poore's suggestion about dry closets and the disposal of domestic water on the garden is only possible in the case of small communities where each cottage has a sufficient area of garden and where the water supply is relatively small. The moment you have an abundant water supply the domestic water is so considerable that you must then lead it away in pipes to some sump?—I quite see the point.

34322. That seems to be the next stage?—Yes.

34323. So the earth-closet system is only applicable on a small scale to small communities?—But I think a domestic supply of water by pipes is not nearly so urgent if the people use earth-closets, because there is no inducement to poison the wells.

34324. The two things have to be considered together, that of water supply and sewage disposal. Sewage disposal becomes at once much more difficult the moment you have an abundant water supply?—That is so.

34325. Then the next stage after the earth-closet system and the disposal of domestic water over the surface of the garden seems to be the introduction of a sump. You may have your earth-closets and you have abundant domestic water which is taken in to some sort of sump pit, and I gather that you thought those pits ought to be so constructed as not to leak. Now, the question of leakage the Chairman raised just now. You told us that in practice, however careful they may be constructed in the first instance, they are made—deliberately made—to leak. Well, is there any objection to their leaking, assuming there is no well in the immediate neighbourhood, is not their leakage a positive advantage?—Is it not exceedingly rare that there should not be any well in the neighbourhood?

34326. Clearly, if there is a well in the neighbourhood, for instance, a well in the same garden, it is a most objectionable arrangement, is it not?—My experience is that there always is.

34327. And the question of water supply must be considered with it. If there is a pipe supply from a distant source, the leakage of the sump does not appear to be a disadvantage, and may in some respects be considered an advantage. If the sump is built of open brickwork, a large amount of liquid will drain away into the surrounding garden ground, and assuming that there is no well being used in the immediate neighbourhood, there does not appear to be much objection to it?—It does not seem to me to be a very wholesome thing to pour sewage indiscriminately on the ground in that way, even for the people living about it.

34328. But is it much worse than pouring it on the surface?—Certainly; because it is shut away from all air and light. This is the point. As long as it is exposed to air and light the especial bacteria connected with it worked in a particular way, that is one thing, but the moment you shut it up in a cesspool and different bacteria get to work to produce compounds which are deleterious rather than useful as manures—I speak under the correction of doctors who know much more about these matters than I——

34329. (*Chairman.*) That is quite right.

34330. (*Colonel Harding.*) The next stage would be how these cesspools could be emptied. In certain cases they are emptied by the proprietor?—That is the usual method.

34331. Does he pour it over the garden, or what does he do?—That is what I used to do myself; that is the usual thing.

34332. The existence of a sump of that kind because water-closet stuff goes into it makes it quite valuable when it goes on to the garden; a wise gardener would rejoice in it?—No, he does not; the manurial value of stuff that comes out of a cesspit is exceedingly minute.

34333. Even with the water closet?—Yes, that is exactly what I do mean. I do not say it is of no value.

34334. I have met several gardeners who have used this, and a great deal of it, who emptied their sump in that way. Your idea that if the sump is emptied by the proprietor he must look upon it merely as a useless function which he performs to prevent any overflow, a perfectly useless function and a trouble?—Of very slight manurial value; I think I said almost none.

34335. If it had some, and if the spread of it over the garden does not cause a stink, at all events that would be to some extent useful?—Excuse my saying so, of course it causes a most colossal stink; the work had to be done at four in the morning.

34336. It ought not to be emptied by the proprietor over his garden?—Generally, he does not want to do it; it means extra cost, it means a horrible smell and disgusting work.

34337. You suggest it should be done properly by somebody?—I am suggesting in some cases, in order to avoid sewage and water schemes, the District Council should simply pump the thing out by a pump.

34338–34351. But you disapprove of the whole thing?—I disapprove of the whole thing, but in many cases there is no power to shut up a cesspool owing to the sanitary bye-laws.

34352. (*Colonel Harding.*) I would like to ask Dr. Fowler if he suggests that these sumps should be emptied by the authority by means of a motor tank and pump. What is to be done with the matter so pumped up? Where is it to be disposed of?—It will be put on the land somewhere where it is least offensive.

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34353. And I think what you objected to in the garden will be in the field ?—It will be a long way from human habitation. The Rural District is a fairly large area; it must be surely possible to find somewhere where it is not a nuisance.

34354. Do you know any communities where it has been adopted ?—No. I was having a long talk with a prominent member of the next District Council, and we came to the conclusion, after thinking it all over, that was the simplest way.

34355. It will be somewhat expensive ?—Well, not compared with the sort of schemes I am dealing with in my evidence.

34356. There is a fatal temptation, is there not, to adopt the water carriage ?—There is.

34357. The moment you have an abundant supply it seems to me impossible to resist the necessity of water carriage and of drains ?—But I have yet to be convinced that a pipe supply is in the least necessary in most country villages.

34358. If you have an abundant water supply in a district and the moment you have people who insist on having water closets, are you not bound to have a drainage system and the water carriage ?—Yes ; but my contention is that both are unnecessary in properly managed villages.

34359. Favourably as one looks upon the system of earth-closets and the disposal of these matters in a man's own garden, the conclusion is reached very soon that it is only practicable on a very small scale in rural districts, little villages of 100 to 200 inhabitants. The moment you get to 1,000 inhabitants the principle of water closets must be adopted, and especially where there is an abundant water supply. It is difficult to see anything more convenient than water carriage ?—I admit the convenience of water carriage, but nothing else, if I may say so.

34360. I remember one village of about 700 or 800 people where they had earth-closets, and the results were very unsatisfactory. They had wells, and they poured their domestic water over the garden, and they were immediately at the foot of the well, so the whole arrangement was very unsatisfactory, and they adopted a drainage system, which seems to have worked very well, especially as they have a distant water supply; the health of the district has improved.—Are they really earth-closets in which a certain amount of earth was thrown on the material ?

34361–34371. There were originally; they all have water-closets now, with an abundant water supply brought by pipes from a distance, and, of course, that involved the necessity of drains. You see, we are obliged as a Commission to look at these matters from a somewhat general point of view, and however desirable the earth-closet seems to be on a small scale, I am afraid it is not very practicable on a large one.

34372. (*Mr. Tatton.*) I thought that you agreed that the water part of the scheme was a necessity, the water supply ?—No, sir.

34373. You do not ?—If the cesspools had been built properly with overflow and the walls cleaned out, we should have gone on with our wells. That is why I do not see the necessity for a water supply as a rule.

34374. And your wells are already polluted. Can you keep them clean ?—Exactly.

34375. On the supposition that you will keep out all deleterious matter from them ?—Yes.

34376. Do you think it is good having these shallow wells in country districts ?—I see no harm if they are properly bricked and curbed.

34377. Is it not almost invariably dangerous with these shallow wells in a country district ?—Not on sandy soil. Sand is a very good filter bed.

34378. Even with a sandy soil and wells, no sewerage, I found it most unsatisfactory. You cannot keep your cesspools perfectly tight. I do not know any place. It is extremely difficult to do. Is not that so ?—It can be done.

34379. The theory is, it can be done; but in practice it is extremely difficult, is it not ?—I did not know it.

34380. (*Chairman.*) The experiment made by Dr. Poore was this :—He had a well practically at the door, 8 or 10 feet off, and he manured the garden with earth-closet manure quite near it, practically within 6 or 7 feet of the well, and there was absolutely no contamination of water ?—The nitrogen values went up in the well, but there was no general contamination by poisonous bacteria or poisonous products.

34381. (*Mr. Tatton.*) There you have a man who looked after the thing himself, but where you have 400 or 500 people, each cottage with its own well and a sink and a cesspool, do you think it reasonable to expect those to be kept pure ?—Not, perhaps, if the cesspool is there.

34382. But supposing that is a difficulty, and it is a serious difficulty, that means you must have a water supply for that place ?—Yes.

34383. And can you tell us what portion of this cost is for water and what for sewage ?—I can tell you for two of them, I think. The total amount borrowed, which is not at all the same thing as the total cost, is £10,181 for Aspley Guise ; £4,527 for Aspley Heath ; £9,748 for Woburn Sands. That was the amount which we were allowed to borrow. Of course, in addition to that we had to pay, as I say, out of income a great deal. The water for Aspley Guise was £4,373 for works and £876 for machinery ; that is £5,249.

34384. It is just half ?—The sewage was £4,932 for Aspley Guise and £2,086 for Aspley Heath. I have not the figures for Woburn Sands ; they are in another county.

34385. They are probably about the same amount. You would have saved half if you had had the water and then used the sewage over the land as you suggest ?—Yes, but, as I say, taking Aspley Guise, I still maintain a water scheme was not necessary either. It is not the cottagers who have cesspools ; it is only the villas. There are not so many of them ; they could have been dealt with firmly. If they had made them watertight and had cleaned them out properly, and we had purified our wells, shut them down for a bit, disinfected them for a bit, there is no reason why we should have had another water scheme.

34386. Were there great complaints about the water before in the district ?—No ; complaints of trouble of pumping sometimes because people wanted lots of baths.

34387. Had you not diphtheria and so on there ? Had you not any epidemics at all ?—No. The diphtheria that started the whole thing was part of a big epidemic of diphtheria over the whole country, and the County Medical Officer points out that it was not a local thing.

34388. Were the wells generally polluted ?—They showed, on chemical analysis, quantities of nitrogen, which showed that they had been in contact with organic matter, but they equally showed that in the case of a well half a mile from a habitation where the organic matter of human origin was thoroughly negligible.

34389. Were they all the same ?—No ; some were worse than others. As far as I could get from taking one of the most infected wells and having a bacteriological analysis made at my own expense, there were no bacteria which could be identified as deleterious.

34390. (*Colonel Harding.*) No intestinal bacteria ?—No intestinal bacteria, but there is an enormous thickness of sand, and this seems to filter it. It cannot filter what is in solution, the nitrites and nitrates ; it filters all the solid.

34391. (*Chairman.*) They do what we do with our water supply in London ?—Quite so.

34392. (*Mr. Tatton.*) If you keep your wells, you would have to give up your baths and water-closets ?—I do not know. The class of community that wants baths gets them ; the class that does not want them does not wish for them, except the weekly bath.

34393. (*Sir Thomas Stafford.*) You give the population of Aspley Guise as 1,500 ; is that the last census ?—I took it from the report of District Medical Officer of Health.

34394. You do not know whether the population is going up or going down ?—I should think it is going up slightly an account of the fact that there are two big employers of labour there, a printing works and a builder; going up very slightly.

34395. But you have not got the census return ?—No.

34396. What class of houses have you got in Aspley Guise ?—I do not quite understand how to answer that

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question. There is an unusual number of what one might call big houses.

34397. Villas ?—No, bigger than villas rather. You would not call them quite mansions, and you would not call them villas. It has always been a residential place from the sixteenth century, so there are several biggish houses, who employ a good deal of labour in the way of gardeners and coachmen, and so on.

34398. A good many villa residences too ?—There are roughly, I should think, about thirty or forty of these.

34399. These are all people who would require baths and proper fittings for their houses ?—They would all demand them, and they could get them, no doubt.

34400. Is it not reasonable that they should have them ?—I do not think it is reasonable that people should go to the country and claim——

34401. And claim a bath ?—And claim everything that they have in the town.

34402. I think if I lived in the country I should like to have a bath occasionally.—I do myself.

34403. If you have these things, if you have houses fitted in a particular way, you must have some means of getting rid of sewage in those houses ?—Yes.

34404. And the bath water ?—And the bath water On our soil it can go into the ground at once. There is not the slightest difficulty about that, because we live on sand.

34405. Is there not a considerable amount of refuse going out from the houses ?—There ought not to be in a properly managed house.

34406. Is there not all over the villages a certain amount of slop-water ? What is to become of that ? Is it all to be put in the sands ?—It mostly did, and has not done any evil.

34407. Do you think that is a desirable thing ?—I do not think it is very deleterious that the slop-water should go into the soil, meaning sink water and so on.

34408. Yes ; sink-water ?—I do not see it is in the least deleterious.

34409. What do the villagers do with their excreta ?—They used to dig them into allotment gardens.

34410. You think they put it on the gardens ?—Quite a number of them, all those not connected with the sewage scheme.

34411. Have they all gardens ?—Mostly allotment gardens.

34412. The ordinary householder takes the trouble of taking out the slop water and throwing it on the garden. Of course I do not know—I do not know very much about England ; I do not live there ; I am asking you for information. You spoke of the Local Government Board forcing them into a scheme. Will you tell me precisely what you mean by "forcing them into a scheme" ?—That the scheme was compelled to be carried out for, and at the cost of, ratepayers who did not wish it.

34413. What scheme ?—The water and sewage scheme.

34414. Who prepared the scheme ?—The District Council.

34415. Who elects the District Council ?—Two members out of something like forty, are elected by the village in question. Of these one was in favour of it and one was against it.

34416. Are there three towns there ?—Yes.

34417. And they have all got representatives on the District Council ?—Aspley Heath had one member: that would be three from Bedfordshire. But Woburn Sands is on a different District Council and they elected one member on it. The two District Councils comprising (say) eighty people, four of these represented the villages in question.

34418. Do these four people still represent them though they went against the wishes of the people ?—Three out of the four, I think.

34419. Still represent them ?—Yes.

34420. So they were not put out for misrepresenting them ?—No ; because most of them did their best to stave it off : it was such a microscopic vote on the Council.

34421. Anyhow this is not the scheme of the Local Government Board ; this is the scheme of the Rural District Council, is not that so ?—That is so.

34422. I rather gathered from your statement—I do not know the procedure in England—that this is a scheme of the Local Government Board ?—I do not think I have made any statement, if you will excuse me, to that effect.

34423. Well, you have criticised the Local Government Board so strongly that I rather thought that interpretation might be put upon it. However, we may be quite clear now that this is a scheme of the District Council and that an inquiry was asked for. Who asked for the inquiry ?—The District Council. It is the only body that can move in this matter, I think.

34424. I see ; and the District Council moved in this matter, and asked for an Inquiry about it ?—And asked for an Inquiry.

34425. Why should the District Council ask for the Inquiry ?—Why should it ?

34426. Yes ?—It is the Sanitary Authority for the district.

34427. Yes, but some person presumably put the District Council in motion ?—Yes.

34428. Was it the people of the District who put them in motion ? Who asked for water and asked for sewers ; somebody must have asked for them ? As a matter of fact was there not a complaint from your district to the District Council about the condition of things and the want of water and the want of sewers ?—No. The only complaint to the District Council was that the overflows from cesspools went into a particular brook which ran through the land of a particular man. I cannot say that there were not any other complaints, but that is the only one I know of.

34429. Was it not the people of the district who demanded an Inquiry and forced the District Council to go on with the scheme ?—No. I was not there at the time, but I do not think that was the case as far as I can remember.

34430. You quote from Sir George Newman, who is a great authority, and say, "In spite of the cost, it must be admitted that the expenditure would have been amply justified if the health conditions of Aspley Guise had been bad. In 1907 Sir George Newman, then County Medical Officer of Health, made a special Report which showed : (1) The almost entire absence of water-borne disease, (2) A normal general death-rate, (3) A very low zymotic death-rate, (4) No abnormal epidemic diarrhœa or diphtheria." You give this quotation from Sir George Newman's Report, but I have got Sir George Newman's Report here. He was the County Medical Officer of Health at the time, was he not ?—He was County Medical Officer of Health at the time.

34431–3. I see here he says : "The general sanitary condition of these three parishes cannot be considered to be wholly good and satisfactory." He goes on to say : "Now, whilst a public water supply and systematic sewerage cannot be considered as always essential to village communities, experience has shown that where population is more dense and the collections of houses is such as characterise urban communities, these things become sooner or later an absolute necessity of good sanitation. Of the three parishes under consideration, Woburn Sands, and the contiguous parts of the other two parishes which adjoin it, are certainly becoming of an urban character" ?—That is so ; I have the Report here. But my whole point has been not that Woburn Sands did not want it and did not require it : I quite admit that it did. My point is that the other two parishes have been sacrificed to Woburn Sands.

34434. Very well, "In other respects it may be said that the sanitary condition is good and has steadily improved since 1889, when formal complaint as to the condition of things then existing was made by a number of residents to the Local Government Board ?—That again is Woburn Sands. I think that was at the time of the epidemic of diphtheria to which reference has already been made.

34435. Very good ; this does not refer at all to— ? To the Bedfordshire part of the scheme.

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34436. He says, "the contiguous parts of the other two parishes which adjoin it are certainly becoming of an urban character" ?—Well, I dispute it, sir, that is all.

34437. He deals with the whole of these schemes later on and he says: "It is not practicable to suggest any alternative schemes, though these have been carefully considered. Nor is it believed that such alternative schemes, if at all adequate or comprehensive, would work out at a lower cost." That is Sir George Newman's opinion about the scheme in question which the Local Government Board are very severely criticised by you for having adopted ?—That is so.

34438. I think that possibly when you gave us a quotation from Sir George Newman, which favoured your view, you might also have given us a quotation which did not coincide ?—The report is rather a long one. I did seriously consider beforehand; I thought as you had got it, I need not go into it in very great detail. I also quote various conclusions which you have not read: "That the health of the populations resident in these three parishes is, on the whole, remarkably good and compares favourably, etc." There are a great number of things on both sides. I have simply taken those quotations which bear on the wells and the water, the question of water-borne disease.

34439. We will pass from that. In regard to this question now of an illegal act, have you not got a remedy if there is an illegal act in England ?—I do not know where the remedy is in this case where the money is spent and done with.

34440. Surely you have always the Court of King's Bench to fall back upon ?—At whose expense ?

34441. Any person who likes may bring an action against the Local Government Board or the Local Authority. If you really think an illegal act was committed in this case, if you think the Local Government Board behaved illegally in the matter, why surely you have only to take an action and get the whole thing cleared up. I only want to point out that the Local Government Board are quite amenable to the law ?—Quite so. An evasion of the Act is not quite the same thing as doing an illegal Act; the expenses are cut down to come within the Act, therefore the Local Government Board have not committed an illegal act. The provision which was to act as a safeguard to parishes goes; we have had to pay more out of income than the Act ever contemplated them being forced to pay.

34442. At any rate the Local Government Board held this Inquiry and everybody had an opportunity of giving their opinions ?—Yes.

34443. You had an opportunity of trying to convince the Inspector yourself of your views ?—I had.

34444. Did many of the people of the village oppose it ? —What is the village ? If you have ever seen one of these inquiries, hardly anybody ever speaks a word; how should they know anything of engineering, medical things, water supply ?

34445. Surely they know about paying the rates ?—Well, people get up and string out long lists.

34446. If they say this is too expensive a scheme and fight it on these lines, this is an utterly wrong scheme, because it is too expensive, will not the Inspector take that into consideration ?—Well, that was said very largely by the one person who did get up and by myself. A certain man who is now dead also opposed it very strongly, and solicitors were employed to argue the point.

34447. Oh! solicitors were employed. Did they not argue their case ?—They argued their case very strongly. The thing was got round, as I say, by leaving portions out of the scheme.

34448. (*Chairman.*) They ultimately had to be paid for ? —Part of them had been paid for and part of them had not been done at all.

34449. (*Sir Thomas Stafford.*) Will you tell me what alternative the Local Government Board could possibly have put forward to what they have done, that is to say: here is a scheme which is generally approved, which they have inquired into; they find it is a reasonable scheme and they pass it. What alternative is open to them ? The only alternative is to leave the places without water, and the County Medical Officer of Health says this is in a very bad condition ?—I beg your pardon; excuse me, he did not say that.

34450. (*Chairman.*) I did not gather that at all ?—On the contrary he says it is in an exceedingly good condition.

34451. (*Sir Thomas Stafford.*) What he does say is; there has been practically no epidemic; are you to wait for an epidemic before you have a sewage scheme and a water scheme ?—"The health of the populations resident in these three parishes is, on the whole, remarkably good and compares favourably with other rural districts in the County of Bedford. Death rates of all kinds are low, and there is but a comparatively slight prevalence of epidemic disease. From a medical point of view therefore, it does not appear that there is any pressing or urgent need for radical alteration in the external sanitary environment of the people. There is no evidence of any widespread occurrence of water-borne disease."

34452. Quite. "The general sanitary condition of these three parishes cannot be considered to be wholly good and satisfactory ?"—Then he goes on to say what would be wholly good and satisfactory to a man like that is, that there should be a water supply and proper drainage.

34453. The County Medical Officer of Health comes forward and he proposes before the Inquiry that this matter shall be dealt with by sewers and by a proper water supply, does he not ?—I do not think that he quite says that—again, if you will excuse me, I read this Report once very carefully.

34454. It seems to me he does. He says: "It is not practicable to suggest any alternative schemes, though these have been carefully considered" ?—Well, if I may say so, it was quite possible to suggest many alternative schemes, but I no not know what the suggestion was, because I was not then in the County.

34455. "For example, a water supply, plus the necessary re-drainages and cleansing of cesspools, combined with scavenging, would work out at a capital and current cost not less than a water supply and proper sewerage as proposed." ?—I am afraid I cannot; I think nobody would really seriously agree with that.

34456. You quote Sir George Newman as an authority ? —On medical matters.

34457. So far as he agrees with you ?—Yes, on medical matters.

34458. You were at this Inquiry ?—Yes.

34459. You had a full opportunity of being heard ?—Yes.

34460. You had an opportunity of giving the views you have given here ?—I was only beginning to develop them.

34461. You gave them a fairly good sketch of your views on the subject ?—I did what I could.

34462. And they did not impress the Inspector ?—Apparently not.

34463. And he adopted the alternative ?—He adopted the alternative.

34464. And you are displeased ?—I am only displeased because I believe it has been a substantial hardship on the village. To me, personally, it is cheaper. I do not have to pay a man to come in and pump my water, but on the village it is a very serious financial hardship. I am displeased on that ground.

34465. What are the rates at present ?—4s. 4d. in the half-year.

34466. What were the rates for the whole of last year ? —10s. 5d. and then 8s. 2d.

34467. How does that compare with your neighbours' rates ?—In the next village I think the rates are 2s. 6d. in the year. That is a purely agricultural village. What they are going the other way, I cannot say.

34468. To villages that are really like yours, is that a terrible burden ?—Well, it is from 2s. 6d. to 3s. more than they were when I went there before the scheme.

34469. (*Chairman.*) Dr. Fowler was kind enough to ask me down to see the place with the possibility of my settling there. The question of the rates startled me at once.

34470. (*Sir Thomas Stafford*). Is this rate likely to continue ?—I think so, because the repairs bill is increasing every year, the work was so badly done.

34471. (*Mr. Tatton.*) The rates have been reduced ?—Yes. In 1911, 3s. 10d.; a special rate in 1912, 5s. 3d. that would include 9d. They jump about rather.

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34472. (*Sir Thomas Stafford*). Yes, but I take it, you borrowed a considerable amount of money, you borrowed twice the assessable value did you not ?—We borrowed twice the assessable value, yes.

34473. And then you pay a difference out of rates ?—We pay the difference out of rates.

34474. That only lasts a certain number of years ?—That was the reason why we had a heavy rate in 1912.

34475. That is a purely artificial rate. That is not to continue unless you have other expenses ?—I have said here ; "although the interest on loan will diminish, the cost of repairs will increase. Against this must be set a small scavenging rate, which has ceased, but seems likely to be partly renewed in the immediate future. What it has cost tenants and property owners to connect the sewers and water-mains, one cannot even estimate. But the deplorable result is, that, so far as I can ascertain, the rents of cottages has been raised by ninepence to a shilling per week. I need hardly emphasise the seriousness of this to mechanics and labourers." I do not think that will be so, the rates will be the about same.

34476. (*The Secretary.*) The two years assessable value limit does not mean that they are not allowed to spend more than that amount, it simply means they are not allowed to borrow more ?—They are not allowed to borrow.

34477. What you call an evasion of the Act is merely that they have to reduce the amount of their loans to the limit ?—Yes.

34478. It is not really an evasion. They are not entitled to borrow more than that ?—When a scheme like that is proposed, it is understood that the Local Government Board does lend the money for the scheme, not only a portion of it. The rest of it has to come out of the rates.

34479. No ; they lend all the money they can ; and it is understood the balance must be got out of revenue ?—That is the very first time I have heard that we have had to do it.

34480. It was understood, was it not ?—It was not in the least understood by the Clerk of the Council who is a well-known solicitor in these parts.

34481. That they would not have to pay ?—He never understood the point you are putting, that the Local Government Board expects the balance to be paid out of revenue.

34482. If it has to be paid out of the revenue, because they will not allow a larger loan ?—The matter was so bad that one half-year we had no money ; we had to levy a district rate on the other parishes, and practically borrow from them—we have since had to repay them—to their extreme annoyance, being rated for Aspley Guise.

34483. The limitation of two years was not to the expenditure, but simply to the expenditure that might be raised by loan ?—I never understood they were two things.

34484. You had to cut it down to that amount?—We understood at the Inquiry that the two things were identical.

34485. If the expenditure is more you could raise it out of revenue, that is the position ?—Yes.

34486. (*Dr. McGowan.*) There are those two points, the question of flies in the drier products ?—In the proper earth-closet, the fly is impossible. The pull of the handle covers the whole thing up with a layer of earth, but with the pan-pail closet it is a very difficult thing, a very dangerous thing from that point of view that I reprobate.

34487. Do you consider face wire netting or wire gauze or a door a necessary thing ?—To the pail-closets ?

34488. No, to either ?—I should not have thought it to be necessary with the proper earth-closet system, because the fly cannot get to the material on which to lay its eggs.

34489. There is this other point which I think has not come out quite clearly. Assuming that you have earth-closets with pails with fœcal matter and a certain small proportion of urine ?—Yes.

34490. In addition there is four-fifths of the remaining urine to be dealt with somehow ?—Yes.

34491. And you have slop water and bath water, those three classes of waters could be dealt with, and what I did not feel quite clear in my own mind about is how are they to be dealt with in a village of small houses with a tiny strip of garden, say. Have you thought the matter out to see how the thing could be done ? I am asking for information ?—I have tried as far as possible. It depends entirely on the amount of garden, the matter of the fluids, and, small as the garden is, certainly in our part of the country, most houses have ample garden for that ; I will not say all. Of course, if there is nowhere to throw it, I quite admit it becomes a serious thing. The little cottages where there is no garden have no means of getting rid of it, are places which will not have a sewage scheme ; they probably will not be connected to the sewers, quite tiny cottages, even if there is a water-borne system ; a rental of 1s. 6d. a week is not enough.

34492. (*Sir Thomas Stafford.*) Just one question ; do you not think it would have been a very strong step on the part of the Local Government Board to have thrown out this scheme proposed by the Rural District Council, a scheme for water and for sewage for one or two villages, and to tell them that they will not give a loan for this purpose ?—I cannot answer that, because I do not know how far they consider themselves to be in the position of protectors of the villages. The point I want to make is, that the Local Government Board should take the view of protectors of the villages against expense.

34493. The Local Government Board's duty is to see, as far as they can, that these people have the best means of protecting health, and then their position is to see that no obstacle is put in the way of the Rural District Council to carry out the business which they are there for. After all, the Local Government Board is more a guiding authority, and where the Rural District Council puts a scheme on all fours with probably hundreds of other schemes, before the Local Inquiry, would it not be a very serious step for the Local Government Board to take to say: no, we will not lend you money for this scheme ?—By the time it got to that position, it would be a serious step, but is it not possible to consider the state of things before enquiries have been employed and trial wells have been sunk, that the Local Government Board should investigate the circumstances before such steps are taken.

34494. The Local Government Board do not come into it till a later period ?—Could they not, that is what I mean, do that ?

34495. Unless there is an outbreak of disease calling their attention to it, they do not come into it. The sanitary matters are in the hands of the Local Authorities appointed for that purpose ?—Who know, of course, as a matter of fact, nothing of the various sciences that bear on the point. They are not engineers, they are not medical men, they do not know anything whatever about the matter ; they are farmers and clergymen and a few gentlemen of leisure.

34496. They put forward a scheme on all fours with hundreds of other schemes that come up on the same lines saying they want water and sewers, and for the Local Government Board to say we will not lend you money for that purpose because Dr. Fowler or somebody else has got another scheme, would be a very strong step ?—By the time it had got as far as it had on this occasion, I admit it would be a strong step.

34497. Your criticism of the Local Government Board, I thought, on reading it, was perhaps a little bit strong ; "a flagrant evasion ?"—Well, the Act says that you shall not borrow more than a certain amount. I understood that was synonymous with, you shall not spend more than a certain amount.

34498. The Local Government Board are empowered, under the Act, to lend twice the assessable value up to that ; do what you like outside that ; the Rural District Council can do what they like with their own revenue.

34499. (*Chairman.*) We are very much obliged to you.

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- Scattered houses in villages generally drain into a convenient ditch, 33111–5.
- The drainage and a system of sewage disposal should be encouraged, 33116.
- Waste water disposed of by throwing over garden, 33117–20.
- Privy middens in such cases better than pails; discussion, 33121–5.
- Nottinghamshire villages can generally get a water supply, 33126.
- Sewage disposal necessary where there is a water supply, 33127–9.
- County Authority have no power to carry out scheme of water supply: in many villages public water supply is available, 33130–2.
- If several villages combined they could obtain water supply at a reasonable rate, 33133.

HANDFORD, DR. H.—*continued.*
Advisable that persons should be encouraged by Local Authorities to dispose of sewage on their gardens, 33134.
Different methods for dealing with house waste may be adopted on the same premises, 33135.
Cesspools necessary for houses above a certain size, 33136.
No harm in leaky cesspools if distant from the water supply, 33137–41.
Absorption of sewage dependent on nature of surrounding soil, 33140.
Statement that deleterious liquids are transformed after soaking through 5 feet of soil referred to, 33142–4.
Discussion as to disposal of house refuse: public scavenging advisable, 33145–7.
Contractors available, 33148.
Refuse generally taken to farmers, 33149.
Agricultural value of refuse, 33150–1.
Spoilt by being mixed with ashes in this country, 33152–3.
Growth of public scavenging in villages, 33154.
Refuse from towns brought into rural districts; no sanction from the local Sanitary Authority required, 33155–7.
The local authority should have some control in the matter: trouble caused by the practice; canal water poisoned, 33158–9.
Proper water supply required where canal water is poisoned: many towns destroy much refuse by burning, 33160.
Trouble will diminish with more burning of refuse, 33161.
Consent of the Local Authority to disposal of refuse from a town in their district should be required subject to appeal to Local Government Board, 33162–5.
Many complaints received on the subject: no power at present to stop such disposal, 33166–7.
Expense prevents action being taken under the Public Health Acts against the town authority in respect of the nuisance, 33168–70.
Appendix to Evidence in support of the proposition that sewage disposal works can be economically provided and used for small populations: details respecting four hamlets in the Basford Rural District in which septic tanks, etc., are in use (p. 60).

HARLEY, PROFESSOR EDWARD VAUGHAN BERKELEY, M.D. (EDINBURGH), M.R.C.P., F.C.S., UNIVERSITY COLLEGE, UNIVERSITY OF LONDON (*Analysis of his Evidence*):
Has a farm at Walton with fourteen cottages, 33389–90.
Small cesspits *versus* pails: advantages of cesspits: particulars respecting, 33391 and 33397.
Action of District Surveyor (or Sanitary Inspector) in regard to privy windows criticized: question as to his powers, 33391–5.
Chargeability of cost of inserting privy windows, 33396.
Requirements of District Surveyor in regard to drains and cesspools for cottages referred to and criticised, 33397–402, 33406–9 and 33421–2.
Bad result of storing slop water in large cesspools, 33403.
Blocking effect of potato parings and tea leaves in slop water drains, 33404–5 and 33409–10.
Simple arrangements necessary for labourers, 33409.
Healthy state of villagers under existing conditions, 33411–2.
Present method of disposal of sewage satisfactory: disposal of slop water in some cases a difficult question, 33413.
Not aware of any instruction of cottagers on the question, 33414.
Condition of ditches into which slop waters flow, 33415–9.
Bad effect of slop cesspool introduced by District Surveyor, 33420 and 33426.
No protest to District Council: instructions of District Surveyor carried into effect, 33423–5.

HARLEY, PROFESSOR EDWARD VAUGHAN BERKELEY—*continued.*
Retention of slop water in cesspools; putrefaction results, 33426–9.
Better that the slop water should flow direct into ditch, 33430 and 33435.
Grating prevents solids from passing into slop water cesspool, 33431.
Suspended matter not carried by drains into ditch: old drains have gratings on them, 33432–3.
Introduction of storage cesspools for slop water a mistake, 33434.
Induces an ærobic instead of ærobic fermentation, 33435.
Disposal of house sewage by householders quite practicable in little communities, 33436.
Has not discussed the matter with neighbours, 33437.
A different question for larger villages where there is sewerage, 33438–9.
At Brickhill and other larger villages there is daily or frequent scavenging by carts, 33440–1.

HOWARD, SIR E. S., K.C.B., CHAIRMAN OF THE WYE FISHERY BOARD (*Analysis of his Evidence*):
Statement handed in respecting the pollution by tin plate works of the Wye at Lydbrook and Redbrook in Gloucestershire, 32544.
Fishery and scenery of river affected, 32545 and 32550.
Fishery Board powerless unless fish are killed by pollution: owners of fisheries can take action, 32546.
County Council have not taken up any complaints, 32547.
No complaints as regards spoiling water for drinking purposes, 32548–9.
Discolouration of the Wye by wash, or swilling, water, 32551–3.
Large volume of swilling water, 32554.
Does not kill fish, 32555.
Because it is diluted with river water, 32556.
Worse in a dry summer, 32557.
Destruction of enormous number of fish then, 32558.
Copperas recovered in some works but not in others, 32559–60.
Swilling water discharged at night: it kills some fish, but does not interfere with fishing in day time, 32560–1.
Fish do not rise when swilling water is present, 32562.
No use dealing with pickle unless the swilling water also is dealt with, 32563.
Swilling, or wash, water, 32564.
Volume of swilling water should be reduced and used for pickling, 32565.
This would involve some expensive alteration of present and long established system but should be done, 32505–6.
Cost not yet estimated, 32567.
Continuous flow of swilling water, 32568–9.
Becomes worse in quality, 32570.
Contents of tank pass into river, 32571.
If it were stored and discharged continuously during the 24 hours the effluent might be less harmful, 32572–3.
Discharge of strong acid by certain works into river, 32574–5.
Copperas can be recovered but its value may not meet expense, 32576–7.
Weaker washing waters expensive to deal with, 32578.

JOHNSON, ALDERMAN RICHARD, J.P., *see under* Robinson, Harvey, etc.

JOICEY, EDWARD, CHAIRMAN OF THE SOUTH TYNE COMMITTEE OF THE TYNE SALMON CONSERVANCY BOARD (*Analysis of his Evidence*):
District of his committee, 32173.
Tyne seriously polluted by collieries and lead works, 32175 and 32200.
Detailed information as to the mineral pollution, and its effects on the Tyne, 32179–189.
On fish in the Nent, 32188–9.

JOICEY, EDWARD—*continued.*
Sewage pollution, 32190.
Not seriously deleterious to fish, 32191–2.
Tyne fisheries not very valuable, 32193.
Fishing rights, 32194.
Tyne could be made a good salmon river if it were not polluted, 32195.
Law requires that death of fish by pollution must be proved before starting a prosecution, 32196.
Destruction of spawning beds the principal damage, 32197.
Fishery Boards have no power as regards spawning beds, 32198–200.
Pollution from railway embankment material, 32200–2.
Whether iron effluents can be purified at moderate cost by filtration through limestone is a question to be considered, 32201.
Impossible to avoid pollution from railway embankment material in some places, 32202.

LADDS, G. W., *see under* Bargate, G. and Ladds, G. W.

LEAD MINING, *see under* Trade effluents, mining.

LOCAL GOVERNMENT BOARD, *see under* Authorities, etc.

MARTIN, C., *see under* Stocker, T. M., etc.

MATHEWS, WILLIAM WEVILL, REPRESENTATIVE OF THE TAVY, WALKHAM AND PLYM FISHING ASSOCIATION, AND THE TAMAR AND PLYM FISHERY BOARD (*Analysis of his Evidence*) :
Duke of Bedford interested in the local fisheries, 31973.
Chief sources of pollution of the Rivers Tamar, Plym and Yealm, 31977.
Effect of china clay works, 31977–83,
Of effluent from mines ; salmon and trout destroyed and meadow lands injured (p. 7, and 31985–6).
Consent of Local Government Board to action against Phœnix Mines under Part III. River Pollution Prevention Act, 1876, refused, 31988 and 32030–6.
Pollution of River Tavy by the Devon United Mines, 31989.
Effluent from these mines, 31990–6.
Pollution of the River Inney by the Bowithick mine ; process of obtaining wolfram ; effect of the pollution : damage to fish ; Rivers Pollution Prevention Act, 1876, of no assistance, 31999.
The River Inney, 32000–3.
Damage to fish and agriculture, 32004.
Fishery in rivers flowing into Plymouth Sound, 32006.
Practicability of mines stopping pollution by their effluents : discussion as to, 32007–12.
The fisheries more important than the mines, 32013–5.
Area and powers of Fishery Board, 32016–7.
Practically no remedy at law for these local pollutions, 32018–22.
Rivers Pollution Prevention Act, 1876 : difficult to obtain conviction under, 32025–8.
The Prince of Wales Mine, 32035.
County Council of Cornwall now make no attempt to deal with the pollution, 32038.
County Council of Devon take no action, 32039.
Helpless position of Authorities in regard to the pollution, 32040–2.
Fishery Board think that owners of mines could materially reduce pollution from mining effluents, 32043.
Method of dealing with suspended matter in mining effluents, 32044–8.
The Lady Bertha mine : poisonous matter in effluent dealt with, 32049.
Damage to fish caused by flooding of old mining shafts, 32050.
Question as to responsibility of mining owner for the damage, 32051–2.

M'VAIL, JOHN C., M.D., MEDICAL OFFICER OF HEALTH FOR THE COUNTIES OF STIRLING AND DUMBARTON (*Analysis of his Evidence*) :
Statement handed in dealing mostly with administrative difficulties in connection with :
Administrative areas, p. 1.
Officials, p. 2.
Tidal Rivers (*Gareloch, Carron, Leven*), pp. 2–3.
Coal dross pollution, p. 3.
Sampling of effluents, p. 3.
Establishment of new manufactories, p. 3.
Flooding of adjoining lands, p. 3.
Watershed Boards desirable as a centre of administration for rivers pollution ; reasons stated, 31914 and 31918–20.
Central Authority to which appeal could be made desirable, 31915 and 31921.
Watershed Board for the Kelvin or for the Clyde, 31921.
Inadvisable to require Local Authorities to completely purify effluents flowing into tidal waters ; case of the Gareloch referred to, 31922–3.
Sufficient to keep suspended matter out of the flow, 31924.
State of the Carron River, 91924–9.
No seaweed growth in the Carron, etc. rivers, 31930.
Coal dross pollution of the River Bonny, 31931.
Difficulty arising from old heaps of coal dross, 31933–4, and 31936–7.
Might be puddled with clay, 31935.
Discharge of excremental matter into the River Leven : trouble with Angling Association, 31938–9.
Liquid trade waste passing into the Leven, 31940–5.
Salmon going up the Leven, 31946–7.
Relative value of fishing rights damaged and cost of purification, 31948.
Reasonable to compensate fishing owners instead of removing pollution, 31949–50 and 31954.
Doubtful whether fish are injured in the Leven, 31951–3.
Drainage into the Clyde : dry closets preferable for the adjacent houses, 31955–9.
But no complaints, 31960.
Flooding of low lying country drained by the Kelvin and other Scottish rivers, 31963.
Watershed Board could deal with such cases, 31964.
Septic tanks might hurt fish in the Leven River, 31965.
Great flow of water carries crude sewage down, 31966.
No mud-banks on the Gareloch, 31968.
No *ulva latissima* or seaweed on the shores of the Gareloch, 31969–71.

MICHELMORE, HAROLD GAYE, CLERK TO THE TEIGN BOARD OF CONSERVATORS ; AND ROWELL, T. PITTS (*Analysis of their Evidence*) :
Statement by Mr. Michelmore read respecting the pollution of the Rivers Teign, Bovey, and Lemon by different works and sewage in the past and the present, 32087.
Tidal river at Newton, 32088–9.
River Lemon subject to serious pollution by a mine 32090.
Jurisdiction of Teign Board of Conservators, 32091.
Formed under Salmon Fisheries Act, 1861 ; insufficient power to deal with pollution of River Teign, 32092.
No use to call attention of the County Council to the matter, 32093.
Immediate action required generally, 32094.
No general river authority in Devonshire, 32095.
Local and fishery boards should have power to deal with river pollutions, 32096 and 32098.
Board formed to protect fisheries, 32097.
Mines in the district mostly very small, 32099.
Powers of County Council limited and dependent on consent of Local Government Board, 32100–1.
No attempt made by County Council to stop pollution from mines, 32102.
Fishery Board has not applied to County Council in the matter ; no use, 32103–4.
Statement by Mr. Rowell respecting serious pollution of River Lemon by mines ; destruction of fish ; cattle on the meadows will not drink the water, 32106.
Arsenical poisoning of fish, 32106–9.
Tin and arsenic mine the cause, 32108.

MICHELMORE, HAROLD GAYE, AND ROWELL T. PITTS—*continued.*
- Lands adjoining River Lemon are meadows let for grazing purposes, 32110.
- Doubtful whether letting value has decreased, 32111.
- Loss of fishing and letting values through pollution of river; no fish left, 32112–7.
- Agricultural loss not serious, 32118.
- Water might kill cattle if they drank it, 32119.
- Agricultural letting value of land not yet affected, 32120.
- Takes some time to affect that, 32121.
- Mine owner once re-stocked river with fish but will not admit cause of pollution, 32122.
- No application yet made to County Council to get pollution stopped, 32123.

MISCELLANEOUS POLLUTIONS (*other than* those caused by Sewage and Trade effluents):
- Cleaning out Liverpool waterworks causes great nuisance, *Bund*, 32146–50.
- Pollution from railway embankment material, *Joicey*, 32200–2.
- Tipping of refuse on river side by Local Authorities, *Raine*, 32274.
- Accidental discharge of gas tar in the River Dee and resulting damage to fish life, *Onions*, 32798 and 32832–7.
- Pollution of the River Hull by tar and gas washings and injury caused by spraying of roads near streams by tar, *Moses*, p. 100.
- Tar spreading on roads, complaints respecting, *ib.*, 32882–3.
- No legal action taken to prevent, *ib.*, 32884.
- To prevent river pollution from it the surface drains must be stopped and the water turned on to land, *ib.*, 32885–7.
- The trouble lasts for about a week after the road has been tarred; cases referred to, *ib.*, 32888.
- Lead poisoning, *Cushny*, 34035–56.
- Arsenic, *ib.*, 34051–72, 34097–8 and 34107–12.
- Copper, *ib.*, 34073–80.
- Chromium, *ib.*, 34081–2.
- Bichromate of potash, *ib.*, 34083–6.
- Manganese, *ib.*, 34087–90.
- Danger point in minerals in drinking water uncertain, *ib.*, 34091–2.
- Caustic soda, *ib.*, 34094–5.
- Arsenical iron, *ib.*, 34099–101.
- Suspended metallic matter in water, *ib.*, 34102–4.
- Zinc, *ib.*, 34113–5.
- Tin and antimony, *ib.*, 34116–24.
- Oxide of iron not a serious poison, *ib.*, 34125.
- (*For other pollutions see under* Sewage *and* Trade effluents.)

MOSES, C. V., CHIEF WATER BAILIFF, YORKSHIRE FISHERY BOARD (*Analysis of Evidence*):
- *Statement* sent in respecting the destruction of fish by pollution of the water in Hewenden Reservoir and the River Aire near Cottingley Bridge, Bingley; pollution by coal washings; of the River Don at Penistone by ochre water; and of the Rivelin and Locksley brooks; pollution by coke ovens; sewage pollution of the River Swale and tributaries, the River Nidd, Oak Beck, Harrogate, and River Aire; pollution of the River Hull by tar and gas washings; and injury caused by spraying of roads near streams by tar, pp. 44–45.
- Steps taken or to be taken in connection with Hewenden Reservoir, 32842–6.
- And the River Aire, 32847–8.
- Fishery Board and the West Riding Rivers Board work in harmony, 32849 and 32855.
- Fishery Board can only act under the Fisheries Acts, 32850.
- Injury to fish dealt with by the Rivers Board, 32851–2.
- Fishery Board cannot act unless fish are killed: independent action is then taken, 32852–4.
- Fishery Board can take action quicker than Rivers Board, 32854.
- Slag washing, 32856–9.

MOSES, C. V.—*continued.*
- Coal washing, 32859–60.
- Bad effect of wool effluents in sewer, passing into river kills fish, 32861–3.
- Proceedings taken in consequence were dismissed for reasons stated, 32864–7.
- Lime and waste from stone works destructive to fish; chokes their gills, 32868–70.
- Nature of the waste deposit, 32871.
- Accumulates in the Humber, 32872.
- Trouble in the River Nidd and the Oak Beck from the Harrogate sewage farm, 32873–4.
- Filters for storm overflow water not efficient, 32875.
- Oak Beck a storm water river, 32876.
- Brings sewage with it from sewage farm into the Nidd, 32877–8.
- The Nidd rendered uninhabitable for fish by it, 32879 and 32881.
- Storm water generally does not affect the Nidd, 32880.
- Complaints in connection with tar spreading on roads, 32882–3.
- No legal action taken against District Councils in consequence, 32884.
- To prevent river pollution from it the surface drains must be stopped and water turned on to land, 32885–7.
- The trouble lasts for about a week after the road has been tarred; cases referred to, 32888.

ONIONS, J., SUPERINTENDENT OF THE DEE FISHERY BOARD (*Analysis of his Evidence*):
- *Statement* respecting the River Dee, its fish, and effluents discharged into it, 32798.
- Many of the effluents are detrimental to fish, 32799.
- No legal action has yet been taken in respect of effluents, 32800–2.
- Several of the collieries treat their discharges, 32803.
- Methods adopted by collieries, 32804–7.
- Great variation in volume of mine water from different mines, 32808.
- Mine water the worst effluent in the Dee, 32809.
- Bad effluent from the Gweryeet Colliery, 32808–11 and 32813–4.
- No attempt made to treat some effluents, 32798 and 32812.
- Particulars of works discharging into the Dee, 32815–8.
- County Council does not supervise or exercise their powers over the Dee, 32819 and 32821.
- The Fishery Board are the active authority, 32820.
- But they have no funds to enable them to bring pressure on offenders, 32822–4.
- Factories and mills on the Dee in urban districts, 32825.
- They cannot run effluents into sewers, 32826–7.
- Counties through or by which the Dee flows, 32828–30.
- County Councils should take joint action: serious pollution by Hawardenbridge Iron Works, 32831.
- Accidental discharge of gas tar and resulting damage to fish life, 32798 and 32832–7.
- Polluting effluents from other works referred to: destruction of fish, 32837–8.

PARKER, DR. J. GORDON, F.I.C. (*Analysis of his Evidence*):
- Difference between fellmongers and tanners, 33449–51.
- Goatskins, 33452–3.
- Process of fellmongering, 33454–5.
- Fellmongers, 33456.
- Treatment of skins by putrefaction, soaking, lime, and bacteriological action, 33457–66.
- Tanning, 33467–9.
- Chrome tanning, 33470–3, 33524–7.
- Does not pay to recover chrome from effluents, 33474–5 and 33521–3.
- Oil tanning, 33476–81, 33528–30.
- Alum tanning, 33482–7.
- Dyeing leather, 33488–90.
- Use of disinfectants by tanners, 33491–4.
- Use of arsenic, 33495–8.
- Use of oakbark, 33500–1.
- Liquor from tanneries, 33502–11.
- Fellmonger's effluents, 33512–7 and 33598–609.

PARKER, DR. J. GORDON—*continued.*

Treatment of solids after settlement, 33518.
Spent tan, 33519–20.
Trouble caused by works: anthrax, 33531–9.
Treatment to prevent anthrax, 33538–9.
Situation of tanneries, 33540–6.
Leather dressers and their effluents, 33547–8 and 33554a–5.
Further tanning by leather dressers, 33549–51.
Works in London, 33552–4.
Purification of liquor from tanneries, 33556–9, 33569–86, 33590–2 and 33681–7.
Works at Dartford, 33559–63.
Connection with sewers, 33564–75.
Gelatine factory effluents, 33587–9 and 33711–2.
Standard of purification for tannery, etc., effluents advisable, 33593–7.
Financially practicable to purify effluents, 33598, 33647 and 33700–7.
Treatment of effluents in Hamburg and Dartford, 33604–26.
Foulness of fellmonger's effluents due to ignorance, 33628–32.
Unnecessary foulness, 33632–5.
Fellmongers' effluents good for fish, 33638.
Not large in amount, 33639–40.
Possible to purify, 33641, 33667–9 and 33688–90.
Recent improvement, 33643–6.
By settling tanks, 33648–9.
But effluents still putrefactive, 33650–1 and 33697–9.
Flushing of tanks during heavy rains, 33651–5.
Fellmongers' works widely scattered, 33656–7.
Skin scrapings valuable for making gelatine, 33658–9.
Methods adopted in fellmongering, 33660–2, 33670.
Foul liquors from, 33663–6.
Lime and putrefactive liquors the trouble, 33671.
Tanners do more to purify their effluents than fellmongers, 33672.
Lancashire, Yorkshire and Scottish fellmongers' effluents the best, 33673–5.
Tanner's effluents: communication with streams, 33676–8.
Obligation to purify tanners' and fellmongers' effluents might sometimes destroy the industry, 33690–6.
Tanners' effluents not yet completely purified, 33708–10 and 33712.
Difficulties of leather manufacturers in connection with the disposal of their effluents, 33713.

PARSONS, DR. H. FRANKLIN, LATE ASSISTANT MEDICAL OFFICER TO THE LOCAL GOVERNMENT BOARD (*Analysis of his Evidence*):

Statement handed in, 32956.
Nottingham closets, 32963.
Night soil of little value as manure, 32964–6.
Extract from Report made in 1892, 32967.
Methods adopted in different localities, 32967–8.
Water carriage less costly and less offensive, 32969–72.
Larger volume of sewage with water closets, 32973–4.
Conveyance of infection by flies, 32975.
No earth used with midden privies, 32976.
Earth closets in India blamed for spread of typhoid by flies, 32977.
Dry closet system impracticable in towns, 32978.
But suitable for rural districts, 32979–81.
Disposal of excrement as manure, 32982–5.
With little effect as a fertilizer, 32986.
Water closets suitable for large houses in the country but not for the smaller ones, 32987–8.
Disposal of liquid refuse where dry closets are used, 32989–92.
Vault privies for excreta, 32993.
Difficult to get earth for dry closets without garden, 32994.
And earth must be dried, 32995.
Troublesome to do so, 32996.
Must be stored in sheds; ashes an inefficient substitute, 32997.
Earth closets mainly met with in Dorsetshire and Hampshire: tendency to be used as privies for lack of earth, 32998.

PARSONS, DR. H. FRANKLIN—*continued.*

Bye-laws of local authorities in relation to closets, etc., 32999.
Duty of local authority to enforce bye-laws as to buildings, 33000.
No power to compel use of earth, 33001.
Unless a nuisance results, 33002.
Section 91 Public Health Act, 1875, 33003–5.
Use of human excreta; discussion as to; China instanced, 33006–9.
Duties of women in regard to house sanitation: discussion as to, 33010–3.
Difficulties in connection with drainage works for small urban districts, 33014.
Frequently nothing done as a result, 33015.
Pail closets frequently used, 33016.
Disposal of contents of, 33017–8.
Dr. Poore's "Rural Hygiene" and his experience, 33019–20.
Ignorance and sloth prevent persons from disposing of night soil, 33021.
Discussion as to possibility of educating people in the matter, 33022–5.
Absence of sewers lead to use of cesspools with their attendant nuisances, 33026–7.
Sewerage schemes desirable for parts only of contributing places should be charged on the particular parts, 33028–9 and 33036.
Would reduce opposition from remainder of the contributing places in each case, 33030.
Disposal of the sewage in such cases, 33031–3.
No power at present to require owner of new cottages to provide land for refuse disposal: should be given, 33034–5.
Cost of emptying cesspools: different places instanced, 33037–42.
Nuisances resulting from neglect to empty cesspools, 33043–4.
Defaulting person must abate it at personal cost, 33045.
Persons should be charged with cost of removal of their refuse, 33046.
Connection of house drains with highway drains should be forbidden, 33047.
By local authorities, who should have power to do so, 33048.
Local authorities should have power to forbid water closets where no means for proper disposal of sewage exist, 33049–50.
Each house should have sufficient land for disposal of sewage where necessary: power of appeal to Local Government Board against unreasonable requirements of local authorities, 33051–3,
Supply of deodorising material for earth closets should be kept provided: duty of Inspector of Nuisances to enforce, 33054–6.
Attention called to certain provisions of model byelaws, 33059.

PAULL, J., *see under* Whitworth, J. etc.

PRIOR, DR. J. W., MEDICAL OFFICER OF HEALTH FOR THE WEST BERKS UNITED DISTRICT (*Analysis of his Evidence*):

Recently Medical Officer of Health for Biggleswade Rural District, 33239.
Water carriage system of sewage disposal necessary in large communities, 33241.
But not suitable for small ones, 33242.
Far too expensive, 33243–5.
Dry closets best for small houses, 33246–7.
Method adopted to get people to attend to them, 33248–51.
Deposit of contents in a trench, 33252–6.
Dr. Poore's suggestion, taken from his "Rural Hygiene," 33253–4.
Details respecting working of the system, 33257–61.
Householders require looking after; methods adopted, 33262–6.
Scavenging schemes, advantage of, 33267.
No difficulty with the people, 33268.
Rather expensive: details as to cost, 33269–73.
Should be spread over entire parish, 33273–4.

PRIOR, DR. J. W.—*continued.*

- On the ground that danger to the public health generally is obviated by carrying out such schemes, 33275–7.
- Fixed receptacles should not be allowed, 33278–80.
- Pail closets preferable to privy middens, 33281–3.
- Privies liable to be neglected, 33284–5.
- Details as to the pails used in pail closets, 33286–8.
- Local authority provided scavenging in Biggleswade Rural District, 33289.
- No difficulty in getting dry earth, 33290.
- Suitable dry earth available in Bedfordshire and Berkshire, 33291–2.

RAINE. W. E., CLERK TO THE BOARD OF CONSERVATORS OF THE WEAR FISHERY DISTRICT (*Analysis of his Evidence*):

- *Statement* regarding the Wear Fishery District; the River and its tributaries; sources of serious pollution of the river; coke ovens, chemical works, sewage, etc., and effect of effluents; fish killed, 32272.
- Analysis of water from River Deerness: and
- *Statement* regarding highly polluting effluents from chemical works and their serious effects on that river and the River Gaunless and the Beechburn or Crook Beck; water from gasometer; improvement in effluents from lead mines; and pollution by refuse from quarries, 32273–4.
- Tipping of refuse on river side by Local Authorities, 32274.
- Fish and fishing rights in River Wear, 32275–9.
- Position of lead mines on river, 32280.
- Occasional pollution only from lead mines, 32281.
- Fluor spar used in steel blast furnaces, 32282–3.
- Work in lead mines has diminished but is still an important industry, 32284.
- May increase, 32285.
- Not much smelting at the works but pollution from one last year, 32286–8.
- Occasional pollutions do great harm to fisheries, 32289.
- Many coke ovens and collieries on the Wear, 32290.
- Pollution from these is the most serious on the river, 32291, and 32298.
- Chemical works at Washington on tidal part of river Wear, 32292–7.
- Serious pollution of River Deerness from coke ovens at Sleetburn Colliery and other works destructive to fish, 32298–9.
- Large volume of effluent in proportion to that river, 32300–3.
- River not polluted above colliery, 32304.
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- No litigation by riparian owners, 32314.
- Difficult to prove damage by quarry waste material, 32315–6.
- But probably they silt up the stream and choke fish, 32317.
- Powers of County Council under Rivers Pollution Prevention Act, said to be too limited to prevent casting of non-poisonous solid matter into river; does not prevent flow of river, 32318–23.
- But quarry waste material does, 32323–5.
- County Council and Board of Conservators have taken no action; discussion on the subject, 32326–32.
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- Company still working, but doubtful whether heaps are added to, 32336–7.
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ROBINSON, HARVEY, MAYOR OF OSSETT; GLEDHILL, ALDERMAN, CHAIRMAN OF SEWAGE DISPOSAL COMMITTEE OF DEWSBURY TOWN COUNCIL; AND JOHNSON, ALDERMAN RICHARD, J.P., CHAIRMAN OF SEWAGE COMMITTEE OF BRADFORD TOWN COUNCIL (*Analysis of their Evidence*):

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- *Statement by the Mayor of Ossett* on the subject of trade effluents and rates paid by manufacturers, 34142–4.
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- *Statement by Alderman Gledhill* on the subject of trade effluents and rates paid by manufacturers in Dewsbury, 34156–7.
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- Drainage, 33180.
- Sewerage of Tarleton, 33181.
- No purification of sewage, 33182.
- Volume of river Douglas considerable, 33183.
- Large dilution of sewage by river, no signs of pollution, 33184.
- A tidal river, 33185.
- All kinds of sewage disposal adopted, 33186.
- Considerable use of privy ashpits, 33187–8.
- Description of: use of ashes for garden paths, 33189–90.
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Probably two or three weeks, 32416.
If stored the top water could be run off clear in a day, leaving the sludge at the bottom, 32417–9.
Large areas required for settling, 32420 and 32422.
Resulting effluent almost clear, 32421.
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Many settling tanks required: foreign materials rarely used for settlement in the manufacture, *ib.*, 32364.
Salt probably useless for settling the waste, soap water would cause pollution, *ib.*, 32365–6.
Refuse deposited on vegetation in river, *ib.*, 32374–6.
Growth of vegetation may not be due to deposits, *ib.*, 32377–8.
No damage to fish from china clay industry, *ib.*, 32379 and 32395–6.
A harmless industry, *ib.*, 32380.
Sediment carried out to sea from estuaries, *ib.*, 32402.
Causes only an occasional discolouration of the sea, *ib.*, 32403–5.
The salt water may cause settlement, *ib.*, 32404.
Very little complaint made as to pollution by the industry of streams. *ib.*, 32407.
Possibly there may have been on the River Camel, *ib.*, 32408.
A great proportion of the mica or discolouring matter can be retained if there is sufficient land for the purpose, *ib.*, 32411–2.
Settling in tanks an expensive method, *ib.*, 32413–4.
Takes long to settle in thick condition, *ib.*, 32415.
Probably two or three weeks, *ib.*, 32416.
If stored the top water could be run off in a day leaving the sludge at the bottom, *ib.*, 32417–9.
Large areas required for settling, *ib.*, 32420 and 32422.
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ROYAL COMMISSION ON SEWAGE DISPOSAL.

APPENDICES TO NINTH REPORT.

Introductory Note.

This Appendix contains a report by Mr. Eric H. Richards on the purification of brewery waste, and reports by Mr. A. C. Carter on the purification of wool-scouring and piece-scouring liquors, respectively. The work embodied in those reports was done in collaboration with the senior officers of the Commission, Mr. Colin C. Frye, Mr. G. B. Kershaw and myself, but Messrs. Richards and Carter having been stationed for a considerable time at the three works which were kept under observation, the reports were most fitly written by them.

The paper on the determination of suspended solids in different types of trade effluent owed its origin to the apprehensions of my colleague, Mr. Frye, that some trade effluents might deposit colloidal matter as solid very rapidly.

The notes on the methods of analysis for sewage liquors and effluents may be of some little use to sewage works chemists and others who are specially interested in this branch.

The laboratory work involved in the Ninth Report and in this Appendix was done by Mr. E. H. Richards, Mr. A. C. Carter, Mr. A. F. Girvan, and Mr. G. T. P. Tatham, to whom I would like to express my thanks for their invaluable help.

The two last reports in this Appendix, on comparative manurial experiments with (*a*) dried and (*b*) de-greased sewage sludge, are by Dr. J. A. Voelcker, and by Dr. E. J. Russell and Mr. E. H. Richards, who kindly undertook this work at the request of the Commission. The papers should be read in conjunction with the earlier ones on manurial experiments with sewage sludges, carried out at a number of stations and reported upon by Professor Somerville, Mr. T. H. Middleton, and Dr. Voelcker (Fifth Report, Appendices VIII. and IV).

George McGowan.

Ealing, London, W.
1914.

I.—REPORT ON THE DIRECT PRECIPITATION OF PIECE-SCOURING LIQUOR, AS CARRIED OUT AT MILL NO. 23. BY A. C. CARTER, F.I.C., ASSISTANT CHEMIST TO THE COMMISSION.

By the kind permission of the owners, the method of purifying the piece-scouring liquor at Mill No. 23 was kept under observation by me from February 21st to March 8th, 1911, and a number of samples were taken for examination in the laboratory at Ealing.

The processes carried on at these works consist chiefly of piece-scouring, finishing and dyeing. About 130 hands are employed and about 18 tons of woollen cloth and flannel are turned out weekly. No wool washing is done.

When the crude cloth arrives at the works, it contains about 7 to 10 per cent. of oleine and a certain amount of animal size and farina.

For the scouring and washing of the cloth about 12 cwt. of soap (made at the works) and 26 cwt. of soda ash are used weekly. In the case of very thick cloths, ammonia is occasionally used in addition.

The works run, on an average, for 50 hours per week of 5 days, and when busy turn out about 35,000 gallons of effluent per hour, 60 per cent. of which correspond to soapy liquor from cleansing the cloth and the remaining 40 per cent. to liquors from the dye-house.

The average daily flow may be put at about 250,000 gallons (150,000 gallons crude mill liquor and 100,000 gallons dye-house liquor).

The two liquors are treated separately.

Before treatment each liquor passes into a chamber containing a trough divided into three sections, where it flows through fine copper sieves which collect the flocks and small particles of wool.

The acid liquor which results from the steeping of the flannel in (5 per cent.) sulphuric acid, preparatory to carbonizing, is also sieved separately.

When a piece of flannel is taken out of the acid bath it contains about 4 lbs. of sulphuric acid to every 100 lbs. of flannel. It is then—before carbonization—squeezed through rollers and washed in four changes of water, which generally contain about the following amounts of sulphuric acid :—

	Per cent.
First wash water - - - - -	0·050
Second wash water - - - - -	0·012
Third wash water - - - - -	0·005
Fourth wash water - - - - -	0·005

The greater portion of the acid liquor consists of the first two washings, which are mixed with the mill liquor; the last two, being very weak, are mixed with the dye liquor.

The acid baths themselves are only very occasionally run off, and then in very small quantities at a time.

Treatment of the Soapy Liquors (Mill Liquor).

The purification plant consists of :—

2 " Aqua-thruster " pumps.

3 Rectangular settling tanks, each 52′ × 15′ 6″ × 17′ deep = 36,000 gallons capacity.

2 Triangular-shaped settling tanks, combined capacity = 55,000 gallons (approx.)

Total tank capacity = 163,000 gallons = 1 day's flow.

2 Straining filters, each 27′ × 9′ × 5′ deep, with 2 feet of clinker (only one filter is used at a time and it runs for about a week).

The content of the filters is only 18 cube yards each.

The daily flow of mill liquor is about 150,000 gallons.

3 High-level tanks for storing the acid recovery liquor which has resulted from the cracking of the magma.

1 Low-level tank for storing the acid recovery liquor which has resulted from the cracking of the magma.

The precipitants used are :—

(1) Milk of lime.

(2) Copperas precipitant.—4 cwt. of copperas; 2 to 3 gallons of vitriol; 1 gallon of nitric acid*; 130 gallons of water.

(3) Acid recovery liquor.

The soapy and acid liquors flow into a pump-hole, from which the mixture is forced by the two " aqua-thruster " pumps up to the settling tanks.

If the mixed liquor, now called the mill liquor, is alkaline, the copperas precipitant is added in the pump-hole, but is turned off as soon as the liquor becomes acid.

Before the liquor reaches the settling tanks, it flows through a long baffle-race, at the beginning of which the milk of lime and acid recovery liquor are added.

The " broken " liquor, whose suspended matter consists chiefly of insoluble calcium and iron soaps, passes in succession through two of the three large settling tanks and then flows through the two triangular settling tanks. It finally passes through one of the two straining filters and, after mixing with the effluent from the dye house liquor, discharges into the stream.

Taking the total working capacities of the settling tanks at 36,000 by 2 plus 55,000 = 127,000 gallons, and the average volume of mill liquor treated per day of 10 hours at 150,000 gallons, we get a continuous flow settlement of about 8·5 hours.

Most of the insoluble soaps collect on the surface of the tank.

One of the three tanks is run off by a floating arm about once every 40 hours, and the magma cracked with vitriol. The magma is rendered just acid and allowed to rest. The acid recovery liquor flows into the low-level tank, from which it is pumped up to the high-level ones for use as a supplementary precipitant.

There are several important points to be noted with regard to this method of treatment :—

(1) It is absolutely necessary for a man to be in constant attendance. His duties consist, chiefly, in noticing the type of liquor that is being treated and varying the flow of the precipitants accordingly. If the mill liquor is very acid he turns off the copperas precipitant and adds lime as fast as possible, and *vice versa* if the liquor is alkaline.

(2) Precipitation is never so good when an acid liquor is being treated. This is probably due to the preliminary conversion of some of the alkaline soaps into fatty acids, which would only be very slowly saponified by the lime (if at all) in transit through the settling tanks.

(3) The copperas preciptant, as used, has been found to give the best results, both from the point of view of cost and of precipitation. It is added before the lime, as better results are obtained by so doing. The acid recovery liquid obtained from cracking the magma is added after the lime and acts as a most excellent supplementary precipitant.

(4) Comparison of the costs and the results of different precipitants :—

(*a*) Alumino-ferric gives a fair precipitation, but the resulting magma is very difficult to treat. It is also more expensive than copperas.

(*b*) Perchloride of iron gives excellent results all round for " fulling " liquors, but the cost is much heavier than that of the copperas mixture.

Comparative costs of treatment :—

Copperas - - - - -	2½d. per hour.
Perchloride of iron - - -	1s. "

With the present method of treatment the amount spent on the precipitants is :—

Copperas—about £20 a year, at 22s. to 28s. per ton.
Lime—about £34 a year, at about 20s. per ton (14 cwts. used per week).

Sulphuric acid—about £170, a year.
Nitric acid—about £7, to £8, a year.

The cracked magma from the settling tanks is steamed and hot-pressed, the resulting oil being then refined and finally distilled.

Most of the grease and oils so obtained are made into soaps for cloth scouring and also for wool-washing at other mills belonging to the same owners. Quite a considerable quantity of grease (stearine, etc.) is also sold to outside firms for candle-making, etc.

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* We understand that nitric acid is no longer used in the precipitation mixture (October, 1914).

The residual cake left after pressing is extracted with benzene. The cake after extraction has been tried as a manure, but has been found to be useless, and it is carted to the tip. It still contains some oily matter, which renders it difficult to break up, and only about 1 per cent. of nitrogen. Still, its possible utilization as a manure or otherwise seems worthy of investigation.

TREATMENT OF THE DYE-HOUSE LIQUOR.

The purification plant consists of :—

5 settling tanks, each 18′ × 10′ × 5′ deep.

4 straining filters, each 23′ × 5½′ × 2½′ deep, filled with 9″ to 1′ of clinker laid on a false bottom of perforated boards.

Three filters with a total capacity of 15 cube yards are generally in use. Since the daily flow of dye-house liquor is about 100,000 gallons, the average daily dose is about 7,000 gallons per cube yard.

The liquors from the dye-house consist chiefly of :—

(1) Waste from the dye vats.

(2) Washing water. Sometimes this is very slightly soapy and contains dirt washed out of the flannel.

The liquor flows through the settling tanks on to two or three of the four straining filters. After mixing with the effluent from the mill liquor it passes into the stream.

As will be seen from the figures of analysis given in Table II., the crude dye liquor is not of a strong nature, and the matter in suspension is only about 11 parts per 100,000. The colour of the liquid varies of course with the dyes that are being used. For the sake of economy the dyes are exhausted as much as possible, and in some cases exhaustion is almost complete. With some dyes, however, not more than two-thirds of the quantity of dye used is absorbed by the wool. These dyes are also very difficult to precipitate, and the colour almost invariably persists through the settling tanks and filters and shows in the final effluent.

The chief offenders are :—

(1) Union black J.W.F.
(2) Napthol blue black N.
(3) Patent blue A.
(4) Fast acid green R.H.
(5) Fast acid black R.

During my visit a considerable quantity of Nos. 3 and 4 were being used, and on these occasions the final effluent was always coloured, though not to any great extent. Most of the other dyes appear to be precipitated in transit through the tanks.

About once a month the tanks are sludged* by allowing them to drain into a pit, from which the liquid is raised by means of an "aqua-thruster" pump to two draining filters of fine clinker (each about 15 feet by 12 feet). When fairly dry, the sludge is spaded off the surface and carted to the tip.

The water used in the mill is obtained from three sources :—

(1) A fairly large gathering ground on the surrounding hills.

(2) A small brook.

(3) Another (larger) brook, when it is fairly clear. This sometimes contains hypochlorite from the calico bleachers above, but that is not objected to, as it helps to keep the reservoirs clean.

The water is purified by settlement and double sand filtration. About 200,000 to 250,000 gallons are used per day. The sand for use in the filter beds is washed with the water from a storage reservoir, filled at times convenient for this purpose, chiefly by surface water during the rainy periods. The washing water, which amounts to about 30,000 gallons per day, runs through three settling troughs and then eventually into the brook.

SUMMARY.

The purification effected at this mill consists in the reduction of the suspended matter by means of precipitation and settlement. From this point of view the purification is good, especially with regard to the soapy mill liquor.

The detailed figures of analysis, given in Tables I.–V., show, among other things, that the average figures for suspended solids are :—

	Parts per 100,000.	
Crude mill liquor -	113·0	
Effluent - -	3·0	equivalent to a reduction of 97 per cent.
Dye-house liquor -	10·8	
Effluent - -	6·4	equivalent to a reduction of 41 per cent.

The mixed effluent, as discharged to the stream, gave the (average) figures, among others :—

Organic Nitrogen - - - - - - -	0·73
Oxygen absorbed from permanganate in 4 hours	3·71
Dissolved Oxygen taken up from water in 5 days	7·56
Incubator test - - - -	1 passed 3 failed

While fairly well clarified, therefore, this effluent required further oxidation before it could be classed as good.

A chance sample of effluent, drawn in January, 1914 (Table V.), was very similar in composition to the earlier average samples.

The chief point of interest here is the excellent precipitation and settlement of the soapy mill liquor.

A. C. CARTER.

March, 1911.

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* A chance sample of the sludge, drawn March 2nd, 1911, and examined a fortnight later (after siphoning off some supernatant water), gave the figures :—

	Per cent.	
Water - - -	92·4	
Dry Matter - -	7·6	4·9 Volatile on ignition. 2·7 Non-Volatile.
	100·0	

The dry matter contained :—

	Per cent.
Nitrogen - - -	3·53
Matter soluble in ether, volatile on ignition -	29·4

TABLE I.

AVERAGE CORRESPONDING* SAMPLES DRAWN EVERY HOUR FROM 7 A.M. TO 4 P.M., FEBRUARY 23RD AND 28TH, MARCH 3RD AND 7TH, 1911.†

Parts per 100,000.	Crude mill liquor;				
	Sample No. 1.	Sample No. 6.	Sample No. 15.	Sample No. 20.	Average
Drawn	Feb. 23, 1911	Feb. 28, 1911	Mar. 3, 1911	Mar. 7, 1911	
Analysed	Mar. 3, 1911	Mar. 6, 1911	Mar. 8, 1911	Mar 15, 1911	
Ammoniacal nitrogen	1·20	—	1·50	0·16	0·95
Albuminoid nitrogen	4·18	—	4·88	1·59	3·55
Total organic nitrogen	—	—	6·81	4·01	5·41
Nitrous nitrogen	0·00	—	0·00	0·00	—
Nitric nitrogen	0·50	—	0·36	0·00	0·29
Total nitrogen (Kjeldahl)	5·72	—	8·67	4·17	6·19
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.), at once	7·80	—	13·63	7·22	9·55
Oxygen absorbed from N/8 permanganate at 27° C. (80° F.), in 4 hours	44·4	45·2	71·1	45·3	51·5
Incubator test (by smell)	Passed.	Passed.	Passed.	Failed.	3 passed. 1 failed.
Dissolved oxygen taken up from tap water in 48 hours at 18° C. (65° F.)	35·3	—	28·2	24·9	25·6
Dissolved oxygen taken up from tap water in 5 days at 18° C.	62·2	—	62·6	53·7	59·5
Total hardness (by soap test) (as $CaCO_3$)	60·3	42·4	32·3	22·9	39·5
Permanent hardness (as $CaCO_3$)	56·9	31·9	27·4	16·4	33·2
Total solids	223·6	176·7	543·8	196·0	285·0
Solids in solution	130·8	82·5	369·4	95·4	169·5
Solids in suspension	92·8	94·2	174·4	100·6	113·0
Volatile matter in suspended solids	84·8	90·0	163·8	90·2	107·2
Fat (*i.e.*, volatile matter in ether extract‡)	81·5	35·0	170·7	25·4	78·2
Acidity (as H_2SO_4)	15·2	10·3	4·5	4·4	8·6

* The word "corresponding," as used in Tables I.–V. means that sample No. 1 corresponds to No. 2, and sample No. 3 to No. 4, while those four samples, taken together, correspond to the Final Effluent, No. 5, and so on.

† These samples, of Tables I.–V., or most of them, were put in ice on arrival at the laboratory.

‡ In estimating the fatty matter the liquor, after partial evaporation, was slightly acidified with hydrochloric acid, evaporated to dryness on the water-bath, and the residue then extracted with ether.

TABLE II.

AVERAGE CORRESPONDING SAMPLES DRAWN AS IN TABLE I.

Parts per 100,000.	Mill liquor effluent.				
	Sample No. 2.	Sample No. 7.	Sample No. 16.	Sample No. 21.	Average.
Drawn	Feb. 23, 1911	Feb. 28, 1911	Mar. 3, 1911	Mar. 7, 1911	
Analysed	Mar. 2, 1911	Mar. 6, 1911	Mar. 9, 1911	Mar. 14, 1911	
Ammoniacal nitrogen	0·20	—	0·35	0·32	0·29
Albuminoid nitrogen	0·57	—	0·70	0·50	0·59
Total organic nitrogen	—	—	1·39	1·00	1·20
Nitrous nitrogen	0·00	—	0·00	0·02	—
Nitric nitrogen	0·00	—	0·08	0·02	—
Total nitrogen (Kjeldahl)	Lost.	—	1·82	1·37	1·60
Oxygen absorbed from N/8 permanganate at 27° C. at once	0·59	—	0·96	0·48	0·68
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	4·05	—	5·79	4·57	4·80
Incubator test (by smell)	Passed.	—	Failed.	Passed.	2 passed. 1 failed.
Dissolved oxygen taken up from tap water in 48 hours at 18° C.	2·25	—	3·12	1·94	2·44
Dissolved oxygen taken up from tap water in 5 days at 18° C.	7·50	—	8·64	4·9	6·74
Total hardness, by soap test (as $CaCO_3$)	36·2	—	35·5	50·8	40·8
Permanent hardness, by soap test (as $CaCO_3$)	35·8	—	34·2	47·2	39·1
Total solids	119·9	—	127·9	139·0	128·9
Solids in solution	117·3	—	123·5	137·0	125·9
Solids in suspension	2·6	—	4·4	2·0	3·0
Volatile matter in suspended solids	1·3	—	3·5	1·6	2·1
Fat, volatile on ignition	1·5	—	—	1·4	1·5
Alkalinity (as H_2SO_4)	6·4	16·1	6·4	8·1	9·3

TABLE III.

Average Corresponding Samples Drawn as in Table I.

Parts per 100,000.	Dye House liquor.				
	Sample No. 3.	Sample No. 8.	Sample No. 17.	Sample No. 22.	Average.
Drawn	Feb. 23, 1911	Feb. 28, 1911	Mar. 3, 1911	Mar. 7, 1911	
Analysed	Mar. 2, 1911	Mar. 6, 1911	Mar. 8, 1911	Mar. 15, 1911	
Ammoniacal nitrogen	0·18	—	0·15	0·11	0·15
Albuminoid nitrogen	0·41	—	0·23	0·33	0·32
Total organic nitrogen	1·04	—	0·65	0·66	0·78
Nitrous nitrogen	0·00	—	0·00	0·00	—
Nitric nitrogen	0·14	—	0·14	0·15	0·14
Total nitrogen (Kjeldahl)	1·30	—	0·94	0·92	1·05
Oxygen absorbed from N/8 permanganate at 27° C. at once	0·98	—	0·82	1·02	0·94
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	5·11	3·31	3·91	5·01	4·34
Incubator test (by smell)	Passed.	Passed.	Passed.	Passed.	All passed.
Dissolved oxygen taken up from tap water in 48 hours at 18° C.	3·43	—	3·17	2·50	3·03
Dissolved oxygen taken up from tap water in 5 days at 18° C.	8·52	—	6·31	4·65	6·50
Total hardness, by soap test (as $CaCO_3$)	5·43	5·71	7·57	8·14	6·71
Permanent hardness, by soap test (as $CaCO_3$)	4·29	4·57	5·14	6·74	5·19
Total solids	72·7	46·4	61·5	66·3	61·7
Solids in solution	57·4	37·4	55·7	53·3	51·0
Solids in suspension	15·3	9·0	5·8	13·0	10·8
Volatile matter in suspended solids	7·4	4·8	5·8	10·8	7·2
Fat, volatile on ignition	1·9	—	—	3·9	2·9
Alkalinity (as H_2SO_4)	6·8	6·6	0·6	0·0*	3·5

* This sample was neither alkaline nor acid.

TABLE IV.

Average Corresponding Samples Drawn as in Table I.

Parts per 100,000.	Effluent from Dye House liquor.			
	Sample No. 4.	Sample No. 18.	Sample No. 23.	Average.
Drawn	Feb. 23, 1911	Mar. 3, 1911	Mar. 7, 1911	
Analysed	Mar. 1, 1911	Mar. 7, 1911	Mar. 10, 1911	
Ammoniacal nitrogen	0·10	0·11	0·11	0·11
Albuminoid nitrogen	0·18	0·22	0·20	0·20
Total organic nitrogen	0·36	0·51	—	—
Nitrous nitrogen	0·00	0·00	0·00	—
Nitric nitrogen	0·15	0·08	0·11	0·11
Total nitrogen (Kjeldahl)	0·61	0·70	0·22	0·51
Oxygen absorbed from N/8 permanganate at 27° C. at once	0·69	0·69	0·95	0·78
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	2·61	3·20	4·36	3·39
Incubator test (by smell)	Passed.	Passed.	Passed.	All passed.
Dissolved oxygen taken up from tap water in 48 hours at 18° C.	2·00	3·01	4·51	2·67
Dissolved oxygen taken up from tap water in 5 days at 18° C.	3·20	4·96	5·33	4·50
Total hardness, by soap test (as $CaCO_3$)	7·54	10·68	6·87	8·36
Permanent hardness, by soap test (as $CaCO_3$)	6·31	9·22	6·24	7·26
Total solids	44·2	58·2	59·0	53·8
Solids in solution	38·4	51·9	51·8	47·0
Solids in suspension	5·8	6·3	7·2	6·4
Volatile matter in suspended solids	4·1	4·4	5·8	4·8
Fat, volatile on ignition	2·5	—	5·3	3·9
Alkalinity (as H_2SO_4)	1·4	0·9	1·4	1·2

TABLE V.

AVERAGE SAMPLES DRAWN EVERY HOUR FROM 7 A.M. TO 4 P.M.

Parts per 100,000.	Mixed effluent as discharged.					Final effluent, Chance Sample.	
	Sample No. 5.	Sample No. 10.	Sample No. 19.	Sample No. 24.	Average.		
Drawn - - - -	Feb. 23, 1911	Feb. 28, 1911	Mar. 3, 1911	Mar. 7, 1911		Jan. 12, 1914.	
Analysed - - - -	Feb. 28, 1911	Mar. 3, 1911	Mar. 7, 1911	Mar. 9, 1911		Jan. 14, 1914.	
						Original sample.	After filtration through paper.
moniacal nitrogen - -	0·21	—	0·19	0·19	0·20	0·09	—
buminoid nitrogen - -	0·28	—	0·38	0·37	0·34	0·20	—
tal organic nitrogen - -	0·59	—	0·94	0·65	0·73	0·48	—
trous nitrogen - - -	0·02	—	0·00	0·00	—	0·0	—
tric nitrogen - - -	0·10	—	0·11	0·12	0·11	0·17	—
tal nitrogen (Kjeldahl) - -	0·92	—	1·24	0·96	1·04	0·66	—
ygen absorbed from N/8 permanganate at 27° C. at once -	0·73	—	1·10	0·63	0·82	0·51	—
ygen absorbed from N/8 permanganate at 27° C. in 4 hours	2·77	3·01	4·77	4·27	3·71	3·40	2·34
cubator test (by smell) - -	Passed.	Failed.	Failed.	Failed.	1 passed. 3 failed.	Failed.	—
ssolved oxygen taken up from tap water in 48 hours at 18° C.	3·43	—	3·72	3·51	3·55	3·23	—
ssolved oxygen taken up from tap water in 5 days at 18° C. -	6·34	—	9·56	6·79	7·56	7·04	6·38
tal hardness, by soap test (as CaCO$_3$) - - - - -	18·7	18·0	28·4	23·2	22·1	36·3	—
rmanent hardness, by soap test (as CaCO$_3$) - - -	18·3	16·0	21·1	21·1	19·1	34·4	—
tal solids - - - -	73·3	71·3	87·5	91·2	80·8	—	—
lids in solution - - -	64·5	65·9	81·4	85·1	74·2	—	—
lids in suspension - - -	8·8	5·6	6·1	6·1	6·7	5·3	—
latile matter in suspended solids - - - - - -	5·9	4·2	5·0	4·9	5·0	3·9	—
t, volatile on ignition - -	1·1	—	—	3·4	2·3	—	—
kalinity (as H$_2$SO$_4$) - -	4·6	4·3	3·0	2·7	3·7	7·9	—

II.—REPORT ON EXPERIMENTS ON THE PURIFICATION OF WOOL SUDS BY PRECIPITATION, 17th JUNE TO 7th AUGUST, 1912, BY A. C. CARTER, F.I.C., ASSISTANT CHEMIST TO THE COMMISSION, WITH TWO ADDENDA BY DR. G. McGOWAN AND ONE BY MR. CARTER.

In November, 1911, a preliminary report on the purification of wool suds by precipitation was presented to the Commission by Dr. McGowan and Mr. Frye, and circulated.

This gave a short summary of an investigation of the subject in the laboratory at Ealing, some notes on the work of previous experimenters, and suggestions for further out-of-door experiments on a larger scale. The Commission afterwards sanctioned the carrying out of such larger experiments at Mill No. 48, for which facilities were given by the owners, and it is with these that the present report deals.

Crude wool always contains much foreign impurity in the shape of dirt, grit, grease and fœcal matter. Before the wool can be combed it has to be well cleansed. This is done by washing with soap and alkali (soda ash). The liquor so obtained is called wool suds; it is very foul and greasy.

Suds vary in quality, some being much more greasy and concentrated than others, according to the kind of wool that is being washed. Australian wool gives the most greasy suds. The mixture is a very complex one and the nature of all the constituents is not yet fully known. For present purposes, however, it may be regarded as a dirty, soapy emulsion, varying in strength, but not greatly in composition. It does vary in composition, but not to an extent to affect materially any ordinary precipitation process.

The method of treating wool suds commonly adopted at present is as follows :—

The wool suds are discharged from the washing bowls into continuous settling tanks, where the gritty matter and sand are deposited. The suds are next treated with a slight excess of vitriol in wooden tanks called " seak " tanks, and the mixture is allowed to settle for 3 to 4 hours, after which the supernatant liquor is run off.

The nature of this liquor can be seen from the following figures of analysis in Table I. :—

TABLE I.

FIGURES OF ANALYSIS OF THE PRESENT " WORKS' EFFLUENT," *i.e.*, THE WASTE SEAK TANK LIQUOR RUNNING INTO SEWER.

6 Chance Samples. Parts per 100,000.

No. of sample.	Date.	Ammoniacal nitrogen.	Albuminoid nitrogen.	Total nitrogen (Kjeldahl).	Oxygen absorbed from N/8 permanganate in 4 hrs. at 80° F.	Dissolved oxygen taken up from tap water in 5 days at 65° F.	Total solids.	Volatile matter in these solids.	Suspended solids.	Volatile matter in suspended solids.	Fat.	Acidity (expressed as H_2SO_4).	Hardnes (expresse as $CaCO_3$).
1. WL	July 8th, 1912	7·05	6·65	17·9	178·0	259·0	1,220	448	140	135	120	110·4	269
2. WL	July 16th, 1912	—	—	40·0	218·4	240	1,786	776	251	225	278	46·2	149
3. WL	July 23rd, 1912	—	—	26·3	133·1	—	1,153	434	204	186	144	158·0	260
4. WL	July 30th, 1912	—	—	38·1	254·6	—	1,784	803	438	344	342	51·1	386
5. WL	Aug. 6th, 1912	—	—	25·9	149·1	—	1,316	455	130	116	138	72·0	260
6. WL	Aug. 7th, 1912	—	—	18·2	—	—	915	321	162	151	121	97·6	357
Average - -		—	—	27·7	186·6	—	1,362	540	221	193	191	89·2	280

It will be seen that this liquor is of a nature that would readily set up foul conditions in any stream it was allowed to enter.

Taking the average quantity of grease in the crude suds at about 900 parts per 100,000 (*cf.* Table II.), Table I. shows that about 20 per cent. of this is run to waste in the tank liquor discharged.

Some methods for the purification of this acid liquor were suggested by Dr. Maclean Wilson and Dr. Gilbert J. Fowler in their reports to the West Riding of Yorkshire Rivers Board in 1911.

Their experiments were conducted in the laboratory on a small scale only. Dr. Wilson used lime and ferric sulphate for precipitation, while Dr. Fowler used lime and alumino-ferric. Both methods yielded a liquor amenable to biological filtration, but of excessive hardness.

The costs of precipitation were given as follows :—

Dr. Wilson—Lime and ferric sulphate, 5·5d. to 6d. per 1,000 gallons.

Dr. Fowler—Lime and alumino-ferric, 3·2d. to 3·7d. per 1,000 gallons.

The disparity in these costs is due to the fact that the samples examined by Dr. Wilson contained considerably more fatty matter than those examined by Dr. Fowler, and in consequence required more precipitant; the latter were of much the same quality as the chance samples taken for the Commission (*cf.* Table I.).

From the Ealing laboratory experiments, already alluded to, it appeared that ferric sulphate would be likely to give the best precipitation results.

In March, 1911, on the instruction of the Commission, an extended visit was paid by myself to a fulling Mill, No. 23, to observe the process used there for the purification of the liquor obtained from piece-scouring (*cf.* this Appendix, I).

This process consists in the precipitation of the piece-scouring liquor by an acid solution of copperas together with lime, followed by continuous settlement. The precipitate so obtained is " cracked " with vitriol and the acid magma is steamed and hot-pressed for the recovery of the grease.

The liquor obtained from cracking, which contains iron and lime salts, together with a slight excess of acid, is collected and used along with some fresh precipitant for the next precipitation. It is termed the " acid recovery liquor."

Having regard to the excellent results obtained by this process, when applied to piece-scouring liquor, and in view of the experimental results obtained in the laboratory at Ealing, it was finally decided to precipitate the wool suds at Mill No. 48 by ferric or aluminium sulphate, used in conjunction with the acid recovery liquor.

It must, however, be borne in mind that piece-scouring liquor contains, on an average, only about 80 parts of grease per 100,000, this consisting almost entirely of fatty acids and the oleine washed out of the flannel. It is much easier to treat than crude wool suds.

PRECIPITATION EXPERIMENTS AT MILL NO. 48.

Scale on which the Experiments were conducted.

With the exception of the first, in which 3,000 gallons of wool suds were used, 2,000 gallons was the quantity taken for each experiment.

Description of Plant used.

(1) Two wooden soak tanks, each 14 feet 10 inches by 7 feet 3 inches by 7 feet deep, and of about 5,000 gallons capacity, and each fitted with movable arms for drawing off the supernatant liquor.

(2) A small filter press.

(3) Steam injectors for forcing the acid recovery liquor from one tank to another and also from the press.

(4) Outlet pipes to carry the acid magma from the tanks to the filter press.

The average composition of the wool suds experimented with is given in the following Table II., while the more detailed analyses are to be found in Table VII.*

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* Table XI gives the figures of analysis of 14 *average* samples of wool suds drawn at Mill No. 48 in January and February, 1913; *i.e.* subsequent to the precipitation experiments described in this report. The object in taking these later samples was to see how far the earlier ones of Table II were representative of the general average and also to test whether the amount of precipitant required by a given sample of suds bore a direct relation to the quantity of fat present.

TABLE II.

CRUDE WOOL SUDS AFTER GRIT SETTLEMENT.

Parts per 100,000.

	Number of samples.	Minimum.	Maximum.	Average.
Total nitrogen	10	18·6	60·8	46·0
Oxygen absorbed from N/8 permanganate in 4 hours at 27° C. (80° F.)	10	397·7	617·4	494·1
Dissolved oxygen taken up from tap water in 5 days at 18° C. (65° F.)	5	360·0	542·0	429·0
Total solids*	10	1,792	3,029	2,406
Volatile matter in total solids	10	1,036	1,797	1,448
Fat†	10	574	1,192	912
Alkalinity (expressed as H_2SO_4):—				
(*a*) Due to alkali soluble in water	9	303	477	363
(*b*) Due to carbonates insoluble in water	9	122	210	137

* It was found practically impossible to determine accurately the solids in suspension, but these consisted mainly of fat.

† The term "fat," as used throughout this report, means "fats and fatty acids," determined as a whole after acidification.

The precipitants used in the experiments were:—

(*a*) Pochin's liquid ferric sulphate at 27s. per ton.

(*b*) Spence's M/L sewage cake at 32s. per ton.

These gave the following analyses:—

TABLE III.

PARTS PER CENT. BY WEIGHT.

	Pochin's liquid ferric sulphate. Spec. Grav. = 1·33	Spence's M/L Sewage Cake.
Total ferric oxide plus alumina	9·36	16·83
Total iron, as ferric oxide	5·71	4·48
Total alumina (by difference)	3·65	12·35
Ferrous iron present, expressed as ferric oxide	0·48	1·13

Outline of Process followed.

(1) Precipitation of the wool suds by the sulphate of iron or alumina, together with the liquor recovered from cracking the precipitate of the previous operation.

(2) Settlement of the precipitate.

(3) Drawing off the precipitation liquor by means of a floating arm.

(4) "Cracking" the precipitate with vitriol until the liquor was distinctly acid to methyl orange.

(5) Settlement of the magma.

(6) Drawing off the acid liquor (the "acid recovery liquor") by means of a floating arm.

(7) Pressing the magma for grease.

The amount of precipitant to be added in the first instance was arrived at in the following manner: 3 or 4 half-Winchester bottles were each filled about two-thirds full with 1,000 c.c. of suds, or of suds plus acid recovery liquor, and different amounts of the precipitant were added to each. From the best precipitation result the amount of precipitant for the whole tankful was calculated.

Later, as experience was gained, it was found that the precipitant might be safely added directly to the suds in the tank, taking care to avoid an excess. After blowing in air and steam to mix the contents, a beakerful was withdrawn from the tank; the appearance of the muddy liquid in the beaker was sufficient to indicate whether or not it was necessary to add further precipitant.

When precipitation was judged to be complete, more steam and air were blown in for about 5 minutes, after which the whole was allowed to settle.

It was found that 16 to 20 hours' settlement was necessary, in order to get the best results (*see* Tables IV., V., VIII., IX. and X.).

The liquor (usually about half the contents of the tank) was then drawn off by means of a movable arm. down to about 2 inches from the surface of the precipitate.

The average figures of analysis of the precipitation liquors are given in Table IV., and the detailed figures in Table X. In the first and second precipitation experiments the average figures are from two samples in each case, and in the third from four.

TABLE IV.

PRECIPITATION LIQUORS. PARTS PER 100,000.

Average figures of Analysis; from 2 Samples in the first Series, 2 Samples in the second, and 4 Samples in the third.

	Ammoniacal nitrogen.	Albuminoid nitrogen.	Total nitrogen (Kjeldahl).	Oxygen absorbed from N/8 permanganate in 4 hrs. at 80° F.	Dissolved oxygen taken up from tap water in 5 days at 65° F.	Total solids.	Volatile matter in total solids.	Suspended solids.	Fat.	Alkalinity.	Hardness (expressed as $CaCO_3$).	Oxide iron (Fe_2O and alumir (Al_2O
Series 1, using Pochin's ferric sulphate - -	8·5	3·0	13·7	54·1	20·1	1,084	179	—	—	—	186·5	69·9
Series 2, using Pochin's ferric sulphate and lime	—	—	23·8	100·5	more than 48·0	1,230	306	—	—	—	152·9	5·0 ($Al_2$0
Series 3, using Spence's M/L sewage cake - -	—	—	25·6	64·2	58·9	1,262	261	—	4·1	64·9 (3)	256·2	53·7

The precipitation liquor was in every case brownish and slightly turbid, but with very little apparent suspended matter (about 3 to 4 parts). It possessed the usual wool-suds smell and became very foul on keeping. The figures for hardness are high, but not so high as those of the waste liquor at present produced in actual practice (*cf.* Table I.). They are very considerably lower than those obtained by Drs. Fowler and Wilson in their experiments.

The percentage purification effected on the wool suds by the precipitation is shown in the following Table V.

TABLE V.

	Precipitants used.	Percentage Purification as calculated on :— Total nitrogen.	Oxygen absorbed from N/8 permanganate in 4 hrs. at 80° F.	Dissolved oxygen taken up from tap water in 5 days at 65° F.	Total solids.	Volatile matter in these solids.	Fat.
Experiment No. 1.							
B	Ferric sulphate - - - - - - - -	56·2	89·6	95·1	44·8	86·3	—
C	Ferric sulphate - - - - - - -	57·3	88·3	94·7	49·1	86·5	—
Experiment No. 2.							
D	Ferric sulphate and lime - - - - - -	54·3	77·7	—	37·2	76·9	—
E	Ferric sulphate and lime - - - - - -	—	81·3	—	55·9	79·3	—
Experiment No. 3.							
G	Spence's M/L sewage cake (alumino-ferric) -	57·1	85·2	—	49·2	85·0	98·9
H	Spence's M/L cake - - - - - - -	68·1	85·9	—	50·4	82·3	—
I	Spence's M/L cake - - - - - - -	56·9	86·0	—	55·4	80·5	99·6
J	Spence's M/L cake - - - - - - -	52·5	90·0	—	47·7	82·5	99·7

It will be noticed that the percentage purification throughout was good, especially as regards the fat.

Cracking the Precipitate.

The next step in the process was to crack the precipitate with vitriol, which was added until the liquor showed a distinct acid reaction to methyl orange paper; then, after blowing up with air and steam for a few minutes, the whole was allowed to settle.

After about 10 to 15 hours' settlement, the acid recovery liquor was drawn off by means of a movable arm into two tubs, from which it was forced by a steam injector to another tank. The magma left behind was then ready to be run to the filter press.

It is obvious that, the better the settlement from precipitation, the smaller is the volume of acid recovery liquor produced. It was found, too, that a larger actual yield of grease was obtained from the press when the magma was thick. In practice, therefore, it would be better to store the magma until it had settled to the most suitable consistency. This would mean a considerable saving of filter press cloths, as less acid liquor would be pressed through them.

Pressing.

The method of pressing used is known as hot pressing. The first step is to heat up the press by blowing steam through it. The magma, which has also been warmed by steam, is then forced into the press at a low pressure (10 lbs. per square inch). Steam at a slightly higher pressure is next turned on and stopped when it is seen issuing from all the chambers. The process is continued by successive chargings with magma and steamings until the press is full, the pressure now attained being about 70 to 80 lbs. per square inch.

The press used in the foregoing experiments was not of a modern type. There can be no doubt that better results could be obtained with an up-to-date pattern.

The yields of grease for Experiment 3 are given in the following Table VI. :—

TABLE VI.

Experiment 3

	Type of Wool washed.	Volume of suds used (gallons).	Grease in these suds (parts per 100,000).	Actual weight of grease in these suds (lbs.).	Weight of grease from pressing (lbs.).	Percentage yield.	Volume of magma (gallons).
F	Botany, English and greasy	2,000	1,009	202	130	64	252
G	Botany, English and greasy	2,000	973	195	107	55	668
H	Australian, Monte Video and a little cross-bred	2,000	932	186	86	46	640
I	Cape, English and cross-bred	2,000	796	159	138	87	540
J	Cape	2,000	793	158	86	54	980
	Total	10,000	901	900	547	61	—
	Calculated to a week's flow of 500,000 gallons	—	—	20 tons	12·2 tons	61	—

The cake obtained from pressing was quite hard and came away from the filter cloths readily. It contained on an average 27·8 per cent. of grease.

The total weight of cake produced at the mill per week in this way should thus amount to about 39 tons, containing about 8·1 tons of grease. In practice it would probably be much less, as the above cake was weighed immediately after emptying the press and was therefore in a very moist condition.

Tank Capacity.

It will be seen that the time allowed for the quiescent settlement of the wool suds, precipitated with Spence's M/L sewage cake, ranged from 14 to 24 hours, the average being 17 hours.

In practice, on a large scale, it would be possible to expedite the discharge of a large proportion of the clear top liquor, by providing a special tank for the further settlement of the thin sludge resulting in the first instance from the settlement of the precipitated wool suds in the seak tanks.

The actual precipitation is rapid and complete, clear liquid being seen within a few minutes of the mixing of the precipitant with the wool suds. The precipitate, however, is very bulky and takes a long time to settle down in the tank.

The results of some small experiments indicated that the precipitate might be counted upon to fall through about one-third the depth of the water in the tank in 6 to 8 hours.

The total flow per day would be 105,000 gallons,—80,000 gallons of wool suds and 25,000 gallons of acid recovery liquor.

Hence, if the above time of settlement of 6 to 8 hours were correct, the capacity of the precipitation tanks to be provided would be about 60,000 gallons in six units of 10,000 gallons each.

In addition to this, two deep tanks, each with a capacity of 40,000 gallons, would be required for the further settlement of the thin sludge ; Dortmund tanks would probably serve this purpose very well, as the settlement would then be continuous and the settled sludge could be drawn off as required.

Cracking tanks.

Four wooden or acid-resisting tanks, each of a capacity equal to about 10,000 gallons, would be required for the reception, cracking and settling of the thick sludge.

Tank for acid recovery liquor.

It would also be necessary to provide a tank for the acid recovery liquor. A small one, with a capacity of about 5,000 gallons, would suffice, as the liquor would be used for precipitation almost as soon as it was produced.

On these lines, the scheme of precipitation outlined in this report would necessitate a total tank capacity of about 185,000 gallons for a total flow of wool suds of 80,000 gallons per 24 hours :—

6 tanks, each 10,000 gallons capacity, for precipitation and partial settlement. 2 Dortmund tanks, each 40,000 gallons capacity, for further settlement.	To be built of ordinary material.
4 tanks, each 10,000 gallons capacity, for the cracking and settlement of the precipitate. 1 tank, of about 5,000 gallons capacity, for the acid recovery liquor.	To be built of acid-resisting material.

The above provision of tanks represents more than double the tank capacity required in the present seak tank process.

On the basis of quiescent settlement for 15 hours, the capacity of the precipitation tanks would be about 90,000–100,000 gallons, so that in this case the total tank capacity to be provided would be about 225,000 gallons.

A. C. Carter.

TABLE VII.

ANALYSIS OF WOOL SUDS USED IN PRECIPITATION EXPERIMENTS, AT MILL NO. 48.

Parts per 100,000.

No. of Sample.	Date.	Type of wool washed.	Ammoniacal nitrogen.	Albuminoid nitrogen.	Total nitrogen (Kjeldahl).	Oxygen absorbed from N/8 permanganate in 4 hours at 80° F.	Dissolved oxygen taken up from tap water in 5 days at 65° F.	Total solids.	Volatile matter in total solids.	Suspended solids.	Volatile matter in suspended solids.	Fat.	Alkalinity (as H_2SO_4):— Due to alkaline carbonates.	Due to Carbonate of lime, etc., insoluble in water.
1. A	June 19th, 1912	Cape and Australian - -	14·40	13·64	40·00	516·3	410·0	2,472	1,592	1,067	770	1,073	400·0	126·5
1. B	June 27th, 1912	Cape - - - - - -	9·84	9·40	32·00	455·6	433·0	1,889	1,152	—	—	781	—	—
1. C	July 2nd, 1912	Cape - - - - - -	10·41	21·80	44·10	523·0	360·0	2,212	1,412	—	—	1,000	386·3	121·8
1. D	July 5th, 1912	Cape and cross-bred - -	—	—	41·22	397·7	400·0	1,792	1,036	—	—	574	333·0	124 9
1. E	July 15th, 1912	Cape and medium cross-bred	—	—	18·64	617·4	542·0	3,029	1,797	—	—	1,192	477·0	210·0
1. F	July 19th, 1912	Botany and greasy - -	—	—	50·44	494·7	—	2,374	1,504	—	—	1,009	386·3	126·5
1. G	July 23rd, 1912	Botany and greasy - -	—	—	57·6	446·0	—	2,511	1,534	—	—	973	467·0	174·8
1. H	July 29th, 1912	Australian, Monte Video and a little cross-bred	—	—	60·4	478·5	—	2,640	1,596	—	—	932	409·6	141·5
1. I	August 1st, 1912	Cape, English and cross-bred	—	—	60·8	563·5	—	2,884	1,473	—	—	796	303·0	161·5
1. J	August 6th, 1912	Cape - - - - - -	—	—	55·2	448·2	—	2,252	1,381	—	—	793	467·0	174·8
		Average - - - - -	—	—	**46·0**	**494·1**	—	**2,406**	**1,448**	—	—	**912**	**363**	**137**

TABLE VIII.

SUMMARY OF PRECIPITATION EXPERIMENTS WITH POCHIN'S FERRIC SULPHATE SOLUTION.

	Volume of suds taken for precipitation.	Volume of precipitant added.	Volume of precipitation liquor drawn off.	Time of settlement.	Vitriol added for cracking.	Volume of acid recovery liquor drawn off.	Total volume of acid recovery liquor drawn off and recovered from pressing.	Volume of magma.	Volume of magma actually pressed.	Corresponding to gallons of suds.	Weight of filter press cake.	Weight of grease from pressing.	Number of pressings.	Time required for pressing.
		Experiment 1.	gallons.	hours.	lbs.	gallons.	gallons.	gallons.	gallons.	gallons.	lbs.	lbs.		Hours.
A	3,000 gallons from Cape and Australian wool.	60 gallons Pochin's solution (=795 lbs.)	1,556	24	100	514	1,416	972	836	2,580	624	76	3	11 hours each.
B	2,000 gallons from Cape wool.	1,416 acid recovery liquor from A; 14 gallons (Pochin) - - - - -	2,304	24	56	640	1,170	500	500	2,000	433	47	2	One pressing 7 hours and one 12 hours.
C	2,000 gallons from Cape wool.	1,170 gallons acid recovery liquor from B; 28 gallons (Pochin) - -	1,800	24	80	560	1,400	870	770	1,770	415	62	2	15 hours each.
		Experiment 2.												
D	2,000 gallons from Cape and cross-bred.	1,400 gallons acid recovery liquor from C; 6·8 gallons (Pochin); 55 lbs. lime - - - - - - -	2,720	48	120	486	700	266	240	1,805	232	60	1	12 hours.
E	2,000 gallons from Cape and cross-bred.	682 gallons acid recovery liquor from D; 3·8 gallons (Pochin); 115 lbs. lime - - - - - - -	1,688	18	300	612	This pressing was a failure as the magma had not been properly cracked.							

TABLE IX.

Summary of Precipitation Experiments with Spence's M/L Sewage Cake.

	Volume of suds taken for precipitation (gallons).	Weight of precipitant added (lbs.).	Volume of precipitation liquor drawn off.	Time of settlement.	Vitriol added for cracking.	Volume of acid recovery liquor drawn off.	Total volume of acid recovery liquor drawn off and recovered from pressing.	Volume of magma.	Volume of magma actually pressed.	Corresponding to gallons of suds.	Weight of filter-press cake.	Weight of grease from pressing.	Number of pressings.	Time required for pressing.	Notes.
			gallons.	hours.	lbs.	gallons.	gallons.	gallons.	gallons.	gallons.	lbs.	lbs.		hours.	
	Experiment 3.														
F	2,000 gallons Botany, English and greasy.	240 - - - -	1,112	14	130	748	950	252	230	1,825	232	119	1	9	Very large yield of grease. The press would have taken more press-cake.
G	2,000 gallons Botany, English and greasy.	100 + 950 gallons acid recovery liquor from F.	1,472	19	100 (Sp. Gr. = 1·59).	860	1,520	668	388	1,160	224	62	1	13 (press full.)	One pressing was only sufficient to deal with about four-fifths of the magma in each of the experiments G, H, I and J. A second (7 hours') pressing of the remaining one-fifth was therefore always done, in order that the whole of the acid recovery liquor might be obtained and the cycle of the process not be interfered with. The weight of grease, as given in this table, is calculated (from the first pressing) for the *whole* of the magma.
H	2,000 gallons Australian and MonteVideo, with very little crossbred.	140 + 1,556 gallons acid recovery liquor from G.	1,832	16	100 (Sp. Gr. = 1·65).	1,084	1,780	640	400	1,250	220	54	1	14	
I	2,000 gallons Cape, English and crossbred.	95 + 1,780 gallons acid recovery liquor from H.	1,908	20	100 (Sp. Gr. = 1·62).	1,250	2,028	540	372	1,378	212	95	1	14	
J	2,000 gallons Cape.	90 + 2,028 gallons acid recovery liquor from I.	2,254	24	120 (Sp. Gr. = 1·41).	850	1,900	980	480	980	216	42	1	15	

TABLE X.

Composition of Liquors obtained by the Precipitation of Wool Suds. Parts per 100,000.

No.	Date.	Volume and type of suds used.	Precipitant added (gallons).	Time of settlement (hours).	Volume of liquor drawn off (gallons).	Ammoniacal nitrogen.	Albuminoid nitrogen.	Total nitrogen (Kjeldahl).	Oxygen absorbed from N/8 permanganate in 4 hrs. at 80° F.	Dissolved oxygen taken up from tap water in 5 days at 65°F.	Total solids.	Volatile matter in total solids.	Suspended solids.	Volatile matter in suspended solids.	Fat.	Alkalinity (expressed as H_2SO_4).	Hardness (as $CaCO_3$).	Ferric oxide and alumina.
	Experiment 1.—using Pochin's liquid ferric sulphate.																	
2 A.	June 19th, 1912.	3,000 gallons from Cape and Australian wool.	60	24	1,556	12·9	1·7	16·7	40·4	22·9	1,169	135	3·5	2·9	—	46·0	169·0	40·0
2 B.	June 27th, 1912.	2,000 gallons Cape.	14 + 1,416 acid recovery liquor from A.	24	2,304	8·9	2·4	13·9	47·5	21·3	1,042	167	—	—	—	—	183·3	74·2
2 C.	July 2nd, 1912.	2,000 gallons Cape.	28 + 1,170 acid recovery liquor from B.	24	1,800	8·0	3·5	14·4	60·7	18·8	1,125	190	—	—	—	—	189·7	65·6
	Experiment 2.—using Pochin's ferric sulphate and lime.																	
2 D.	July 5th, 1912.	2,000 gallons Cape and cross-bred.	6·8 + 1,400 acid recovery liquor from C + 115 lbs. lime.	48	2,720	—	—	18·8	88·6	31·1 + x*	1,124	239	—	—	—	—	180·2	5·9 (alumina only).
2 E.	July 15th, 1912.	2,000 gallons Cape and cross bred.	3·8 + 682 acid recovery liquor from D + 55 lbs. lime.	18	1,688	—	—	28·7	112·4	65·0 + x*	1,335	372	—	—	—	—	125·6	4·0 (alumina only).
	Experiment 3.—using Spence's M/L sewage cake.																	
2 F.	July 19th, 1912.	2,000 gallons Botany, English and greasy.	240 lbs.	14	1,112	—	—	22·3	55·1	50·0	1,111	160	—	—	8·8	98·9	148·4	34·2
2 G.	July 23rd, 1912.	2,000 gallons Botany, English and greasy.	100 lbs. + 950 gallons acid recovery liquor from F.	19	1,472	—	—	24·7	65·9	58·4	1,275	230	3 to 4 †	—	11·2	75·9	216·8	50·8
2 H.	July 29th, 1912.	2,000 gallons Australian and Monte Video.	140 lbs. + 1,556 gallons acid recovery liquor from G.	16	1,832	—	—	25·3	67·4	87·0	1,310	275	3 to 4 †		Trace.	89·1	278·2	60·8
2 I.	August 1st, 1912.	2,000 gallons Cape, English and cross-bred.	95 lbs. + 1,780 gallons acid recovery liquor from H.	20	1,908	—	—	26·2	78·7	47·0	1,285	287	—	—	2·9	29·8	293·6	50·8
2 J.	August 6th, 1912.	2,000 gallons Cape.	90 lbs. + 2,028 gallons acid recovery liquor from I.	24	2,254	—	—	26·2	44·6	43·0	1,178	252	—	—	2·1	—	236·0	52·4

* "+ x" means that the oxygen present was exhausted.

† As judged by the eye; these solids were not actually determined.

In order to gain further information with regard to the amount of fat present in the wool suds at Mill No. 48, fourteen further samples, extending over a period of a month, were drawn and examined in January and February, 1913. Each of them was made up of 23 sub-samples, drawn hourly throughout the day. The fat in these average samples ranged from 720 to 1775 parts per 100,000, the average for the whole being 1094 parts (as compared with an average of 912 parts in the samples of Table II.). The figures of analysis of these later samples are given in Table XI. (below), together with the amount of ferric salt required by each sample for complete precipitation in the laboratory. Ferric sulphate was used, but the figures given are in terms of ferric oxide (Fe_2O_3). As will be seen from the table, the amount of precipitant required was approximately proportional to the amount of fat present; only in three instances out of the fourteen was there any marked divergency from this.

TABLE XI.

ANALYSIS OF FOURTEEN AVERAGE SAMPLES OF WOOL SUDS FROM MILL NO. 48, DRAWN BETWEEN JANUARY 23RD AND FEBRUARY 22ND, 1913. EACH SAMPLE WAS MADE UP OF 23 SUB-SAMPLES, TAKEN HOURLY OVER THE DAY AND NIGHT

Parts per 100,000.

No. of Sample.	Drawn.	Analysed.	Type of wool washed.	Total nitrogen (Kjeldahl).	Oxygen absorbed from N/8 permanganate in 4 hours at 80° F.	Dissolved oxygen taken up from tap water in 5 days at 65° F.	Total solids.	Volatile matter in total solids.	Fat.	Amount of precipitant (expressed as ferric oxide, Fe_2O_3) required for complete precipitation:— Per 100 parts of fat.	Amount of precipitant (expressed as ferric oxide, Fe_2O_3) required for complete precipitation:— Per 100,000 parts of suds.
1	January 23rd—24th	January 27th	Cape and English cross-bred - - -	55·7	337	551	3,112	1,936	1,196	19·3	231
2	January 24th—25th	January 29th	Botany and English cross-bred - -	51·8	295	432	2,506	1,650	1,057	20·6	218
3	January 27th—28th	January 29th	Botany and medium cross-bred - -	53·0	313	440	2,811	1,834	1,118	20·6	231
4	January 29th—30th	February 1st	Australian, Cape and medium cross-bred	52·9	305	457[1]	2,690	1,732	1,115	20·7	231
5	January 31st—Feb. 1st	February 3rd	Australian, Cape and medium cross-bred	63·6	353	427[1]	3,242	2,041	1,312	17·6	231
6	February 4th—5th	February 7th	Australian, Cape and skin wool and medium cross-bred	62·4	360	533	3,437	2,244	1,484	17·0	252
7	February 6th—7th	February 10th	Skin wool and medium cross-bred - -	50·1	303	506	2,600	1,587	952	22·1	210
8	February 7th—8th	February 10th	Australian, Cape and medium cross-bred	34·3	226	384	1,745	1,141	720	21·3	154
9	February 10th—11th	February 12th	Australian, Cape and medium cross-bred	41·1	258	471	2,163	1,397	900	20·1	181
10	February 12th—13th	February 17th	Australian, Cape and medium cross-bred	43·0	291	398	2,263	1,596	864	22·3	193
11	February 14th—15th	February 17th	Skin wool, Australian, Cape and medium cross-bred	39·7	283	435	2,133	1,380	835	21·6	181
12	February 18th—19th	February 20th	Cape, Australian and medium cross-bred	91·6	506	850	4,642	2,812	1,775	20·6[2]	366[3]
13	February 20th—21st	February 24th	Australian, Cape and medium cross-bred	55·2	332	340	2,450	1,449	844	27·8	235
14	February 21st—22nd	February 24th	Australian, Cape and A.B., with medium cross-bred	75·8	383	569	2,888	1,822	1,140	22·1	252
			Average figures - - - - -	**55·0**	**325**	**485**	**2,763**	**1,759**	**1,094**	**21·0**	**226**

[1] Five-sixths of 6 days.

[2] 19·9 and 21·3.

[3] 353 and 378.

NOTES BY DR. McGOWAN.

(1) *The Bacterial filtration of the precipitation liquor.*

Some experiments made in the laboratory with a small filter of matured clinker showed that the precipitation liquor was amenable to bacterial purification, thus :

Precipitation liquor (2 E) filtered for 3 days at the rate of 25 gallons per cube yard per 24 hours, gave :—

TABLE XII.

Parts per 100,000.	Liquor (2E).	Filtrate (2E′).	Percentage purification.
Ammoniacal nitrogen - - - - - - - -	—	0·20 (approximate)	—
Nitric nitrogen - - - - - - - - -	—	1·2 (approximate)	—
Oxygen absorbed from N/8 permanganate at 80° F. at once -	38·8	8·8	—
Oxygen absorbed from N/8 permanganate at 80° F. in 4 hours	122·4	29·7	76
Dissolved oxygen taken up from tap water at 65° F. in 5 days	—	4·5	—
Incubator test - - - - - - - - - -	—	Passed.	—

The filtrate (2 E′) was a frothy liquor of deep brown colour, with a musty smell.

A second filtration of (2 E′) at the same rate reduced the 4 hours' figure to 25·0.

A third filtration of (2 E′) at a rather quicker rate reduced the 4 hours' figure to 18·6.*

A fourth filtration of (2 E′) at a rather slower rate brought the 4 hours' figure to 19·2†.

From the above figures it is seen that the organic matter in the filtrate was more readily oxidizable by acid permanganate than by dissolved oxygen, and that even after repeated filtrations the 4 hours' "oxygen absorbed" figure remained very high ; there was thus evidently some very resistant organic matter present.

In order to see whether this organic matter could be made to undergo oxidation rapidly in a bacterial filter, if it were previously mixed with a sewage liquor, further filtrations were made on the fourth filtrate from 2 E, mixed with fully half its volume of a partially oxidized Hendon precipitation liquor, two to three weeks old. There was, however, very little reduction effected in the "oxygen absorbed" figure of the mixture.

Again, the second filtrate from the above mixture (with precipitation liquor) was further mixed with half its volume of settled Ealing sewage, a week old, and this mixture was re-filtered ; but here again very little further reduction in the "oxygen-absorbed" figure was shown.

While these experiments are far from exhaustive, they show that the precipitation liquor from wool suds is amenable to bacterial filtration, so as to yield a non-putrescent effluent. If percolating bacterial filtration of the precipitation liquor from wool suds were to be carried out in practice, it would be advisable to make in the first instance an experiment on an out-of-door scale over a reasonable period of time. It might be found necessary to cover the top of the filter with a layer of material sufficiently fine to arrest any particles of grease left in the precipitation liquor, this layer to be renewed as required.

(2) *The inorganic salts in the liquor from the direct precipitation of wools suds.*

The liquor obtained by the direct precipitation of wool suds is alkaline in reaction, and it is not merely strong organically, but also contains much inorganic salt—mainly in the form of sulphate—in solution. It was thought advisable to examine the ten precipitation liquors of experiments 1, 2 and 3 in this connection. The analyses were carried out by Mr. G. T. P. Tatham, and the results are given in Table XIII.

TABLE XIII.

INORGANIC BASES, ETC., IN THE PRECIPITATION LIQUORS FROM EXPERIMENTS, 1, 2 AND 3.‡
Parts per 100,000.

No. of Sample.	Silica, etc., insoluble in Hydrochloric acid.	Alumina (Al_2O_3).	Ferric Oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Sodium Oxide (Na_2O).	Potassium Oxide (K_2O).	Sulphate, expressed as SO_3.	Sulphuric Acid (SO_3) calculated as necessary to saturate the bases present.
Experiment 1 :									
2 A	3·6	18·5	39·4	17·5	6·5	121	324	524	572
2 B	3·4	20·6	52·2	18·2	5·8	118	189	423	462
2 C	4·1	20·2	46·4	20·6	5·9	165	183	449	529
Experiment 2 :									
2 D	?	0·8	2·4	79·7	1·7	118	149	306	402
2 E	3·4	1·8		52·7	10·8	88	370	194 (?)	—
Experiment 3 :									
2 F	0·7	9·2	28·8	24·5	13·7	139	259	473	537
2 G	3·4	16·6	40·4	35·5	13·0	134	272	510	565
2 H	5·0	36·1	27·2	29·5	Trace	118	266	411	535
2 I	10·0	31·0	30·0	25·0	11·9	106	287	327	544
2 J	5·7	22·7	26·1	25·4	10·9	163	198	425	517
Average	3·9§	17·7	29·4	32·9	8·0	127	250	404	519

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* This estimation made on the paper-filtered sample.

† Done on the settled sample.

‡ The liquors were evaporated to dryness, the residues gently ignited to destroy the organic matter, and then the whole taken up with hydrochloric acid and water in the usual way.

§ Nine samples.

Copying from the foregoing table the *average* figures for the whole ten samples, we have :—

	Parts per 100,000.
Silica and Silicates, etc.	3·9*
Alumina (Al_2O_3)	17·7
Oxide of Iron (Fe_2O_3)	29·4
Lime (CaO)	32·9
Magnesia (MgO)	8·0
Soda (Na_2O)	127·0
Potash (K_2O)	250·0
Nitrogen (N_2)	21·7 (Taken from Table X).

It requires but a glance at those figures to realise that this liquor possesses manurial properties of considerable value. On the other hand, possible danger from anthrax spores must not be lost sight of. The potash averaged 0·4 per cent. by weight of the liquor and constituted two-thirds by weight of the whole inorganic bases. In addition to the potash and nitrogenous matter present, there is probably also a little phosphate (this was not estimated), though most of the phosphate of the original suds is no doubt brought down in the precipitation.

In view of the possibility of such liquors being filtered biologically on a large scale, it might be worth while to test in the laboratory, in the first instance, how far the concentration of the potash could be carried without having recourse to evaporation. To do this, the biological effluent (which would contain all the potash of the original liquor) would have to be used for washing a second portion of the raw wool, and then again precipitated and biologically filtered—and so on. The effluent would eventually become too saline to allow of bacterial filtration, but this might not occur until it was sufficiently concentrated to allow of economic evaporation for the potash salt.

George McGowan.

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* Nine samples.

NOTE BY MR. CARTER ON A SUGGESTED ALTERNATIVE METHOD OF TREATING WOOL SUDS.

The foregoing report on the purification of wool suds by direct precipitation shows that it would be necessary for the mill in question to provide a large tank capacity (185,000 gallons), and it is doubtful whether the small seak tanks at present employed at most works of this kind would be of any use for the purpose.

As the capital outlay for tanks would be rather a serious item of expense, a method of purification which necessitated only *an addition* to the existing plant might in some cases be advantageous and be adopted with less demur.

It is suggested that this object might be attained by the treatment of the acid liquor, which is at present run away after the cracking and settlement of the crude wool suds.

The proposed treatment would consist in the precipitation of the acid liquor with a small quantity of cheap precipitant (alumino-ferric), and a larger quantity of lime, followed by continuous flow settlement.

This process would be similar to that used at the fulling mill, No. 23, for the treatment of the fulling liquor, which is generally acid. The continuous flow settlement at this mill is 8·5 hours.

If a continuous flow settlement of 12 hours were allowed for, a tank capacity of about 50,000 gallons would be required for a daily (*i.e.*, 24 hours) flow of wool suds of 80,000 gallons, thus :—

3 tanks, each 10,000 gallons capacity, of acid resisting material.	30,000 gallons.
1 tank, for further settlement, 20,000 gallons.	20,000 gallons.
	50,000 gallons.

One of the 10,000-gallon tanks would most probably have to be sludged every day.

The sludge could be cracked with vitriol and the resulting magma hot-pressed.

The volume of the liquor from cracking would be small, and this liquor could be mixed with the crude wool suds, thus effecting a slight saving of acid.

It would remain to be seen whether the value of the grease recovered would pay for the chemicals used. Laboratory experiments would no doubt be useful in this connection.

A disadvantage of this process would be the hardness of the precipitation liquor produced, as compared with that obtained by the direct precipitation process.

A. C. Carter.

January, 1913.

III.—OBSERVATIONS ON THE PURIFICATION OF BREWERY WASTE BY SEPTIC TANK TREATMENT AND PERCOLATING FILTRATION, BY ERIC H. RICHARDS, B.Sc., F.I.C., ASSISTANT CHEMIST TO THE COMMISSION, WITH AN ADDENDUM BY DR. G. McGOWAN.

All the waste liquors from the brewery (No. 49) at which the following observations were made, were formerly discharged untreated into a small brook. The pollution from this source, however, became so great as to necessitate the erection of the purification plant, about to be described. This plant was installed in 1904. Since then we are informed that it has been continuously in operation, with very satisfactory results.

This place was selected for observation, as it appeared to demonstrate that a brewery could successfully purify all its waste liquors by a comparatively simple process, at a cost which was not too heavy from the commercial point of view. The installation, as working during my visits, gave very satisfactory results.

Waste Liquors from Brewery.

The brewery produces chiefly two classes of beer, a light ale for private sale and bottling, and a heavier public-house beer. The brewing plant has a capacity of thirty-five quarters and is of modern type, as the brewery was rebuilt about twelve years ago.

The following list gives the various kinds of waste liquor produced on an average working day.

	Gallons.
(1) Cask washings - - - - - -	1,500
(2) Washings from the Brewing Vessels -	100
(3) Washings from the Fermentation squares	100
(4) Washings from the Yeast backs and floors	200
(5) Bottle washings - - - - - -	100
(6) Square water - - - - - -	700
(7) Steep-water (in the malting season) - -	1,000
	3,700

The refrigerating and attemperating water, which is perfectly clean, is discharged to the brook by a separate drain.

(1) *Cask washings.*

The largest volume of the waste liquor treated comes under this head. The number of casks requiring cleaning is rather above the average, as compared with other breweries of the same size, as the nature of the trade demands a large number of small and medium-sized casks. Cask-washing is carried on nearly every day, but the bulk is done on days when there is no brewing, hence the large flows in the early part of the week. The casks are cleaned by swilling out with hot water, which removes the beer dregs and the hops put in when the cask was finally bunged up for shipment. Pieces of cork and other solid matter are also found, but most of the coarse solids are caught by a strainer on the washing trough, and do not pass into the drain. If necessary, the cask is opened and the interior brushed out thoroughly. If the barrel has become acid by standing in the sun or otherwise, washing soda is used to clean it, but normally no chemicals are employed. The clean casks are then placed on steam jets and well scalded out.

The liquor that flows to the purification plant from these operations is always warm (about 40° C.), brown coloured, and with much suspended matter (beer dregs and fragments of hops); it smells strongly of stale beer, but is not usually acid. The flow is very irregular, but at the time of my first visit the average discharge amounted to about 1,500 gallons a day.

(2) *Washings from the brewing vessels.*

As the operations of brewing depend for their success so greatly on the cleanliness of all the vessels employed, a very considerable volume of water is required for washing out the various parts of the plant after they have been in use.

(*a*) *The Mash-tuns* are wooden vessels and require to be carefully scrubbed down with hot water after use. This produces a liquor containing spent grains, with a little sweet wort.

(*b*) *The Underbacks*, or vessels which receive the wort from the mash-tuns, previous to boiling in the copper, are also well washed down. The liquor resembles that from the mash-tuns, but contains less grains.

(*c*) *The Copper boiling vat* also is washed out, but this does not yield a strong liquor, since most of the residue from it is passed on to the——

(*d*) *Hop back*, in which the hops are strained out from the wort on a perforated false bottom.

(*e*) *The Cooler*, which receives the liquor pumped up from the hop back, is a shallow vessel in which the wort cools and aerates, while at the same time a resinous deposit is thrown down. This latter is swilled into the drains when the cooler is cleaned out. The wort is then passed over the——

(*f*) *Refrigerators*, to bring its temperature below 60° F. (15·6° C.), before it passes into the fermentation squares. The refrigerators require to be thoroughly cleansed, by scrubbing the copper tubes after use.

All these parts of the plant (*a* to *f*) contribute together a total of about 100 gallons of wash water per day.

(3) *Washings from the Fermentation squares.*

These are square wooden tanks of from 900 to 2,500 gallons capacity, in which the fermentation of the wort is conducted at a carefully regulated temperature. After the action is complete and the yeast has been separated from the beer, which is run into the settling tuns, the squares are cleaned down, an operation which produces a very thick creamy liquor containing yeast and scum from the tank walls. After cleaning, if the square is not to be used again immediately, it is filled up with clean water, to keep it watertight. About 100 gallons per day would be an average volume of liquor draining from this section of the plant.

(4) *Washings from the Yeast backs.*

The yeast which has been skimmed off the squares is passed to the yeast backs, where it is stored. There is always a surplus of yeast produced, and this is washed down the drains to the septic tank. It constitutes a very strong creamy liquor, but its volume is not large. A small filter press is used to extract beer from the yeast after removal from the squares. The backs are made of slate or wood, and the cleaning of these and washings from the process in this department yield about 200 gallons a day.

(5) *Bottle washing.*

This operation involves the cleaning of the empty bottles with a stream of hot water and a revolving brush. The waste contains beer dregs and external dirt and amounts approximately to 100 gallons per day. (At many breweries the bottle-washing water constitutes a large proportion of the total waste liquor.)

All these waste liquors from the various departments of the brewery mingle in one drain leading to the purification plant, which may be briefly described here. It consists of a septic tank of ample size, which receives the brewery waste, together with the small discharge of sewage and slop-water from the brewery offices. The mixed liquors, after a slow passage through the tank, are pumped on to two percolating filters of coarse material, the effluent flowing without further settlement into the brook.

Sewage and Slop-water.

The brewery waste flows through a small closed brick chamber, where it is joined by the discharge from the single W.C. in the offices, the urinal, and two lavatory wash basins. The proportion of sewage and slop-water to brewery waste is therefore very small, but it was not practicable actually to measure its volume or to sample it. From the nature of the case this would have been a difficult matter, even if the discharge pipe had been accessible. The W.C., urinal and wash basins are used by seven persons during the day only. The flush tank on the W.C. holds 2½ gallons, so that the approximate volume of sewage liquor entering the septic tank is somewhere about 30 gallons a day. It is probably over average strength. The thirty workmen employed at the brewery use a privy which has no water-flushing arrangement, and the excreta do not enter the septic tank, the cess-pit beneath being cleaned out in the usual way from time to time.

Two visits, extending over four weeks and two weeks, respectively, were paid to the brewery, and a number of samples were taken. These were forwarded to Ealing, for chemical examination in the laboratory there.

Table I. gives the figures of analysis for the samples of brewery waste and mixed brewery waste and sewage drawn during the first visit, when no steep liquor was passing through the plant. These samples of brewery waste and of brewery waste plus sewage were average samples, compounded of sub-samples drawn every half-hour during the working day. The quantities taken, so far as could be judged by observation, were in approximate agreement with the rates of flow; but this was of necessity only a rough approximation. Hence the samples cannot be looked upon as perfectly true averages.

TABLE I.

Approximately Average Samples Drawn in March to April, 1911.

No Steep Liquor in these Samples.

Parts per 100,000.	Brewery waste.		Mixed Brewery Waste and Sewage.	
	Extremes.	Average.	Extremes.	Average.
Ammoniacal nitrogen	0·12 — 0·22	0·18 (6)*	1·04 — 2·92	1·47 (6)
Albuminoid nitrogen	2·14 — 4·30	2·96 (6)	2·03 — 4·90	3·06 (6)
Total organic nitrogen	4·70 — 9·34	6·60 (6)	3·39 — 9·71	6·41 (6)
Nitrous nitrogen	—	0·0 (6)	—	0·0 (6)
Nitric nitrogen	—	0·0 (6)	—	0·0 (6)
Total nitrogen (by Kjeldahl)	4·90 — 9·53	6·78 (6)	4·61 — 12·63	7·88 (6)
Oxygen absorbed from N/8 permanganate at 27° C. at once	5·23 — 8·02	6·26 (6)	4·46 — 7·18	5·73 (6)
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	69·0 — 92·6	79·2 (6)	45·7 — 74·5	57·4 (6)
Dissolved oxygen taken up from tap water at 18° C. in 48 hours	35·5 —114·5	94·2 (5)	57·6 —133+x	67·3 (3)
Dissolved oxygen taken up at 18° C. in 5 days	110·4 —203·4	146·4 (5)	105·0 —192·6	135·1 (6)
Incubator test (by smell)	—	Failed.	—	Failed.
Chlorine	2·00 — 3·65	2·74 (6)	1·58 — 3·20	2·52 (6)
Solids in suspension	49·7 —178·6	88·3 (6)	41·3 — 96·3	61·9 (6)
Volatile matter in these solids	43·8 —159·1	77·6 (6)	37·0 — 85·7	54·0 (6)
Solids, *i.e.*, muds, by centrifuge (vols)	241·0 —532·0	334·0 (6)	111·0 —622·0	363·0 (6)

* The figures in brackets give the number of samples tested.

Brewery Waste.—This has about the same amount of total nitrogen as a sewage of average strength, but here the greater part of the nitrogen is organic, whereas in sewage the nitrogen is mostly present as ammonia. The oxidisability, as shown by the 48 hours and 5 days' dissolved oxygen absorption tests, is very high.

Mixed Brewery Waste and Sewage.—As the sewage, though necessarily strong, constitutes only a very small proportion of the mixed liquors (certainly not more than 5 per cent., and probably more nearly 1 per cent.), the figures for the mixture are very similar to those for the brewery waste, the increase in ammoniacal nitrogen constituting the most marked difference.

The Septic Tank.

The mixture of brewery waste and sewage flows by gravity into a brick tank lying rather below the ground level. The tank measures 36 feet by 20 feet by 3 feet 11 inches (average depth), and has a capacity of 17,625 gallons. It is divided longitudinally into two sections, either of which can be worked independently when the tank is being cleaned. In normal working, both sides are used in parallel. The tank is further divided by two transverse baffle walls, and the six compartments so formed are arranged to drain to a sludge well in the centre of the tank. The tank is usually run for about a year without cleaning. When it is emptied, a chain pump is used to lift the sludge on to the ground near the tank, where it is mixed with ashes and carted on to the land. The inlet and outlet pipes are both submerged. After passing through a fine screen (¼ inch), the tank liquor runs to the pump well. There was a thick scum on the tank at the time of my first visit. When it had been working since October, 1909, *i.e.*, for 17 months, without cleaning. It was cleaned again in May, 1911, 8 months before the second visit. The top of the tank is covered with loose corrugated iron sheets, as a precaution against nuisance from smell. There was no smell from the tank itself on either occasion. The septic tank liquor is raised from the well by a No. 2 pulsometer steam pump into two flushing tanks, whence it is discharged intermittently to the sprinklers by an automatic valve. The two tanks have a discharge capacity of 86 gallons each, and the connections are so arranged that they may be discharged into either of the two sprinklers. The discharge from the pulsometer into the flush tanks was very violent, and as the septic liquor had a most offensive smell, the splashing so caused created a nuisance. This, however, could easily be remedied by lengthening the pipe or by covering the flushing tank with a loose sheet of iron.

The Filters.

There are two percolating filters of the following dimensions:—

Area	(each filter)	78 square yards.
Depth	,,	8 feet.
Diameter	,,	30 feet.
Capacity	,,	209 cubic yards.

The material is coarse clinker, not graded, but something like 2 inches to 4 inches in diameter, enclosed by unperforated walls of blue Staffordshire brick, about half the depth (4 feet) being above and half below ground level.

The distribution is by revolving sprinklers with trough arms, working under a very small head. I was informed that nothing had been done to these sprinklers since they were erected in 1904—not even any lubrication of the bearings. They were working well, and there seemed to be little trouble from the choking of the holes in the arms.

There are no tiles on the filter floors and the effluents combine in a long drain running to an outfall into the brook, some 50 yards lower down.

At the times of my visits the volumes of liquor passing through the plant averaged 2,000 and 3,000 gallons per day, respectively, a quantity that the pulsometer, running dead slow, was able to lift on to the filters in 3 to 4 hours. The filters were thus receiving tank liquor at the rate of 41 gallons per cubic yard per day, but as they were resting for 21·5 hours out of the 24, the average rate was only 6 to 7 gallons. Both filters were receiving tank liquor at the same time, but I was informed that it had been the practice to work only one filter for a week or more, while the other rested. No. 1 filter, being the older, had been worked harder than No. 2; it was brought into use before the whole of the clinker was in position, this being added as it was produced at the brewery. This fact may explain the slight ponding noticed on the filter, which was much choked with earthy matter in the upper layers, and did not look very satisfactory. There were practically no worms in the top layers of No. 1 filter. No. 2, however, was quite clean, showed no ponding, and red worms swarmed in the top material. There was no fungoid growth on either filter.

One point of very special interest was noticed in connection with these filters, viz., the comparative absence of suspended solids in their effluents. In March, 1911, the effluent only contained 2·8 parts per 100,000, although the tank liquor going on to the filters had 24·3 parts. I had the heavy stone slabs covering the outlet sumps from the two filters raised (said to be for the first time since they were built), but found no suspended matter in either case. In all sewage filters of coarse material, as is well known, the amount of suspended solid passing away in the effluent is a leading feature, even where the sewage has been subjected to thorough chemical precipitation before passing to the filters. Now, neither of the filters was discharging any appreciable solid, and I was told that they never had done so. The question naturally arises as to whether the filters are holding up such suspended solid and will become completely choked in time, or whether the digestion of the solids, which in the case of a sewage liquor is not very great, is here a factor to be more seriously considered. In view of some recent work on the disintegration of yeast cells, this latter effect would seem to be a possibility.*

The rate at which the filters were worked was of course very slow, and plenty of time was given for the digestion of organic solids.

However this may be, there is no doubt that the filters were producing a very high-class effluent from a strong foul-smelling septic liquor. This result is chiefly due to the ample capacity of the filters.

Septic Tank Liquor.

The prolonged passage through the septic tank brings about a marked change in the nitrogenous composition of the mixed liquors. About 75 per cent. of the total nitrogen is now present as ammonia, formed by the breaking down of the organic matter. This is of special interest, since it has been stated that the tendency of brewery waste liquor to become acid has been a difficulty with regard to its treatment at many places. The tank liquor in question was always quite alkaline in reaction throughout the observations.

The data available do not allow of saying with certainty whether the presence of the small proportion of sewage is essential to this satisfactory result, or whether, if once the septic tank were fully matured with mixed sewage and brewery waste, it would continue to produce an alkaline liquor when fed with the latter alone. The point requires investigation. From the practical point of view it is sufficient to be able to say definitely that the brewery waste, mixed with the very small proportion of sewage liquor from the brewery office only, yielded an alkaline septic tank liquor which could be readily oxidised by biological filters.

The amount of suspended matter passing away in the tank liquor was above the average, as the tank had not been cleaned for seventeen months. The mean figure for suspended solids, taken over a period between two annual cleanings, would probably be about 12–15 parts per 100,000. The solids contain 80 per cent. of organic matter.

Filter Effluent.

The figures in Table II. show that the effluent was exceedingly good in every respect. It was non-putrescible, took up only 0·7 part of dissolved oxygen in 5 days and contained less than 3 parts of suspended matter. It will be noticed that the chlorine figure for the filter effluent is lower than the corresponding figure for the septic tank liquor. This is probably due to the access of subsoil water to the long effluent pipe leading to the brook, at the mouth of which the samples were drawn (*cf.* Effluent at time of second visit).

TABLE II.

Average Samples Drawn in March—April, 1911.
Drawn half-hourly and mixed in equal quantities.

Parts per 100,000	Septic tank liquor.		Filter effluent.	
	Extremes.	Average.	Extremes.	Average.
Ammoniacal nitrogen	5·84 — 6·92	6·34 (6)	0·04 — 0·32	0·15 (6)
Albuminoid nitrogen	0·99 — 1·34	1·15 (6)	0·02 — 0·08	0·07 (6)
Total organic nitrogen	1·72 — 2·55	2·04 (5)	—	—
Nitrous nitrogen	—	0·00 (6)	0·00 — 0·08	0·04 (6)
Nitric nitrogen	—	0·00 (6)	0·92 — 2·12	1·51 (6)
Total nitrogen (by Kjeldahl)	7·81 — 8·75	8·27 (5)	1·28 — 2·51	2·13 (6)
Oxygen absorbed from N/8 permanganate at 27° C. at once	2·28 — 2·87	2·58 (6)	0·09 — 0·26	0·25 (6)
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	8·87 — 12·16	10·37 (6)	0·40 — 1·28	0·75 (6)
Incubator test (by smell)	—	—	—	All passed(6)
Chlorine	2·66 — 3·03	2·93 (6)	1·62 — 2·05	1·87 (6)
Dissolved oxygen taken up from tap water at 18° C. in 48 hours	26·0 — 30·8	28·1 (6)	0·12 — 1·27	0·42 (6)
Dissolved oxygen taken up from tap water at 18° C. in 5 days	36·4 — 75·3	51·1 (6)	0·08 — 1·83	0·70 (6)
Solids in suspension	14·9 — 34·3	24·3 (6)	0·5 — 4·3	2·8 (6)
Volatile matter in these solids	10·7 — 28·3	19·5 (6)	0·3 — 2·3	1·4 (6)
Solids by centrifuge, i.e. muds (vols.)	44·0 —131·0	75·0 (6)	9.0 —44·0	27·0 (6)
Total hardness, by soap test (expressed as parts carbonate of lime, $CaCO_3$)	—	—	24·8 —30·6	27·2 (6)
Permanent hardness (as $CaCO_3$)	—	—	10·3 —12·9	10·9 (6)

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* Dibdin, *Journal of Institute of Brewing*, Vol. XVI., No. 6, p. 535. (July–October, 1910).

Steep-Water.

The Malt-house has two steeping tanks, one holding 8 quarters of grain and the other 24 quarters. The volumes of water added to the grain in each case are 1,000 and 3,000 gallons, respectively.

Steeping is carried on in the winter months only. Each charge of grain is steeped twice, and each steep requires about 48 hours. The steep liquor is run off rapidly into the septic tank by an inlet midway along the side. This must produce some disturbance of the solids, but as nothing can leave the tank until the pump is started, an interval of an hour or two allows things to settle down again, so that no excess of suspended solids goes on to the filters. The total discharge of steep-water at the time of my second visit was about 5,000 gallons per week, this being run off on three separate occasions.

Table III.

The figures given in this table show the composition of the samples drawn on the second visit, in January, 1912, when steep liquor was running through the plant. Only the septic tank liquor and the filter effluent were examined in the laboratory on this occasion. The four pairs of chance samples and the four sets of average samples gave very similar results, as one would expect with such a relatively large tank capacity. If these figures for septic tank liquor are compared with those in Table II., the diluting effect of the steep liquor is shown by the lower numbers for total nitrogen, but on the other hand the more easily fermented carbonaceous matter, as measured by the dissolved oxygen taken up in 5 days, is about double that in the first set of samples. It is characteristic of steep liquor to give very high figures for the dissolved oxygen absorption* test, and the ratio of the 48 hours to 5 days' figures indicates how rapidly fermentation proceeds in this case.

As the septic tank had recently been cleaned out, the suspended solids were comparatively low.

The samples of filter effluent were drawn this time at the separate outlets from the two filters, so as to avoid dilution with subsoil water from the effluent pipe, and were mixed in equal proportions. The average samples of septic tank liquor and effluent show a much better agreement as regards the chlorine figures than the samples of Table II. The effluents were quite as good as before, and very similar to the first set of samples in every way.

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* 6th Report of Commission, pp. 65, 71 and 77.

TABLE III.

Samples Drawn in January—February, 1912.
(These samples all contain steep liquor.)

Parts per 100,000.	Chance Samples.				Average Samples.			
	Septic tank liquor.		Filter effluent.		Septic tank liquor.		Filter effluent.	
	Extremes.	Average.	Extremes.	Average.	Extremes.	Average.	Extremes.	Averag
Ammoniacal nitrogen	2·44 — 3·90 (4)	3·17	0·02—0·16 (4)	0·07	2·06 — 2·40 (4)	2·22	0·00—0·03 (4)	0·02
Albuminoid nitrogen	0·79 — 1·19 (4)	1·00	0·09—0·16 (4)	0·12	0·89 — 1·13 (4)	1·02	0·06—0·11 (4)	0·09
Total organic nitrogen	1·58 — 1·86 (4)	1·73	—	—	1·46 — 2·36 (4)	1·87	0·12—0·20 (2)	0·16
Nitrous nitrogen -	—	0·00	0·00—0·02 (4)	Trace.	—	0·00		0·00
Nitric nitrogen - -	—	0·00	1·06—1·72 (4)	1·52	—	0·00	1·08—1·84 (4)	1·45
Total nitrogen (by Kjeldahl) - -	4·18 — 5·48 (4)	4·89	1·17—2·06 (4)	1·66	3·86 — 4·42 (4)	4·09	1·09—1·98 (4)	1·50
Oxygen absorbed from N/8 permanganate at 27° C. at once -	3·05 — 6·24 (4)	4·22	0·20—0·40 (4)	0·27	3·05 — 8·32 (4)	4·80	0·14—0·26 (4)	0·20
Oxygen absorbed from N/8 permanganate at 27° C. in 4 hours	14·45 — 20·66 (4)	16·23	0·80—1·32 (4)	1·05	15·92 — 18·70 (4)	17·75	0·68—1·08 (4)	0·84
Incubator test (by smell) - - -	—	—	(4)	All passed.	—	—	(4)	All passed.
Chlorine - - -	4·64 — 5·53 (4)	5·17	2·72—4·47 (4)	3·33	4·24 — 6·24 (4)	5·62	4·85—5·17 (4)	5·00
Dissolved oxgen taken up from tap water at 18° C. in 48 hours	59·0 — 77·3 (4)	68·7	0·00—0·41 (3)	0·27	74·5 — 77·0 (4)	75·9	0·30—0·46 (3)	0·36
Dissolved oxygen taken up from tap water at 18° C. in 5 days -	82·8 — 114·0 (4)	100·2	0·53—1·30 (4)	0·87	98·0 — 137·6 (4)	115·4	0·56—1·19 (4)	0·81
Solids in suspension -	7·2 — 17·4 (4)	10·7	1·8 — 5·1 (4)	3·6	6·6 — 10·3 (4)	8·5	0·7 — 1·3 (4)	1·0
Volatile matter in these solids - -	5·7 — 12·2 (4)	8·1	0·9 — 2·8 (4)	1·8	5·2 — 8·4 (4)	7·1	0·3 — 1·0 (4)	0·6

THE BROOK.

The brook is small—some 4 to 5 feet wide—with only a few inches of water in it in dry weather, and rises from springs on the hill-side, within sight of the brewery. It receives the drainage from cultivated land and is rendered turbid from this cause in wet weather. I could find no sign of fungus or any growth of consequence for half a mile above the brewery.

A large manure heap lies at the upper part of the brewery, between the bank of the brook and the piggery. Part of the drainage from this heap and the pig-styes must percolate direct to the brook.*

The outfall from the filters of the purification plant discharges about 100 yards further down the stream. The bottom here is stony and the flow pretty rapid, with plenty of opportunity for aeration. There was some green filamentous growth on the stones, mostly coloured with brown mud.

Generally speaking, the brook might be described as "clean," in the sense defined in the Appendix to the 8th Report, p. 136. Two samples of water drawn a little below the brewery outfall took up, respectively, 0·17 and 0·20 part of dissolved oxygen in 5 days, figures which are in agreement with the observed conditions.

In conclusion, I should like to express my thanks to the Managing Director for the facilities which he afforded for observing the working of the purification plant and for much valuable information as to the volumes of waste from the different departments of the brewery.

Eric H. Richards.

November, 1912.

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* We are informed by the Managing Director that since the above observations on the brook were made, both the piggery and the manure heap have been abolished.

ADDENDUM. BY DR. McGOWAN.

In order to gain an idea of the "strengths" of the different brewery liquors, "long aerations" were made on some of the average samples of series I., *i.e.*, on Brewery Waste, Mixed Sewage and Brewery Waste, and Septic Tank Liquor—nine samples in all. These aerations were done in quarter-Winchester bottles with good stoppers, the stoppers being tied down with tape and then mercury-jointed. Tap-water at 18° C. was used for diluting. The bottles were kept for the greater part of the time at something like 22° C. At the end, the oxygen remaining in solution and in the gas which had collected at the top of each bottle was determined.

The results are given in the appended Table IV. and the conclusions on this page. Although the number of the samples from which these conclusions are drawn is but small, the samples were typical and good.

Conclusions.

1. The "strength" of this brewery waste (containing no steep liquor) is three times that of an average sewage. The strength of the septic liquor is one and a-half times that of an average sewage.

2. Relatively to the amount of (unoxidized) nitrogen compounds present, the "oxygen absorbed" from permanganate in four hours is *very* high in the brewery waste; still high (though less so) in the mixed brewery waste and sewage; and rather low in the septic liquor.

3. The ratio of the tests—"oxygen absorbed" at once to "oxygen absorbed" in four hours—shows that in the brewery waste the amount of very quickly oxidizable matter is relatively low; slightly higher, though still low, in the mixture; while in the septic liquor the ratio is about the same as in a sewage or a septic tank liquor derived from a sewage.

4. As regards oxidizability by oxygen in solution, the relative rates in all three classes of the brewery liquor are much the same as in sewage liquors, *i.e.*, something like one-third of the whole oxidizable matter present is oxidized in the first five days at 18° C. (65° F.).

Further (taking now for comparison the whole of the seven sets of average samples which were comprised in Series I.), about one-sixth, or perhaps a little more, of the total oxidizable matter is oxidized in the first two days.

5. The approximate formulæ[*] for arriving at the "strengths" of the liquors would be:

For Brewery Waste.—(Ammon. + Organic N.) × 4·5 + Ox. abs. in 4 hours[†] × 4·3.

Mixed Sewage and Brewery Waste.—(Ammon. + Organic N.) × 4·5 + Ox. abs. in 4 hours × 5·8.

Septic Liquor from the above Mixture.—(Ammon. + Organic N.) × 4·5 + Ox. abs. in 4 hours × 10.3

6. These results emphasize the reduction in oxidizable matter and the change in quality of the liquor induced by the stay in the septic tank, which has been referred to by Mr. Richards. The reduction is, of course, largely due to the deposition of the suspended solids entering the tank and, no doubt, in some measure to their digestion. How far this digestion goes, we have no numerical data to show; but, judging from the active evolution of gas in the tank, as well as from the highly organic character of the solids in question, the digestion must be relatively great.

7. From conclusions 3 and 4, it is probably safe to infer further that the rate of oxidation, in a percolating filter of coarse material, of such a septic tank liquor should be about the same as for a sewage liquor of the same "strength," though this is slightly modified by the formula arrived at in conclusion 5; *i.e.*, judging from this latter, the rate would be rather slower in the case of the brewery septic liquor. The filter might thus reasonably be called upon to treat about 50 gallons of such a septic liquor per cubic yard per 24 hours and produce a good, well-oxidized effluent.

During the observations the filters were only treating at the rate of 42 gallons per cubic yard per 24 hours during 3½ hours of the day, and resting for the remaining 21½ hours.

Referring to Part IV. of the Report on the Dorking experiments (Fifth Report, App. IV., p. 208 *et seq.*), the curve given there by Mr. Richards shows that a rate of 50 gallons per cube yard, spread over the 24 hours of the day, would mean about 5 hours' actual contact in the filter, with the expected production of an effluent showing about 95 per cent. purification (crediting nitrate). As it was, running for 3½ hours at a rate of 42 gallons per cube yard per 24 hours, an actual purification of 102 per cent. (crediting nitrate) was obtained.

If the 50 gallon rate were continued over the whole 24 hours of the day, either more organic solids would accumulate in the filter, or would be washed out in the effluent, than is at present the case with the much smaller dose.

No estimations were made of the total oxidizability of the septic tank liquors in the second series of samples, when steep liquor was included in the wastes entering the tank. The septic liquor (two chance and two average samples) contained in this case only about half as much ammonia and organic nitrogen, but it was distinctly stronger in carbonaceous matter, as judged by the "oxygen absorbed" in 4 hours, and much stronger, as judged by the dissolved oxygen absorption in 48 hours and 5 days, thus:—

Ammon. + Organic nitrogen.		"Oxygen absorbed" in 4 hours.		Dissolved oxygen taken up in			
				48 hours.		5 days.	
(*a*)[‡] 8·94	(*b*) 4·44	(*a*) 12·0	(*b*) 16·4	(*a*) 21·2	(*b*) 71·5	(*a*) 51·6	(*b*) 111·6

During the second observations, therefore, the tank liquor contained a larger proportion of quickly oxidizable matter, and also, no doubt, more oxidizable matter in the aggregate.

If we apply tentatively the "strength" formula for the tank liquor, arrived at from Series I., to the liquor of Series II., the strength of the latter comes out at about 240; this may, however, be an over-estimate; indeed, it probably is so, for the formula is here more or less speculative.

The data do not therefore allow of a specific estimate of how much of this type of septic liquor the percolating filters might be called upon to treat; but it is safe to say that it would be less than 50 gallons per cube yard per 24 hours—probably something like 40 gallons. It is to be noted that with the treatment of the second tank liquor at the rate of 44 gallons per cube yard per 24 hours, for 4·22 hours of the day, the filter effluents of Series II. were of as good quality as those of Series I.

George McGowan.

Ealing.
November, 1912.

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[*] *Cf.* Fifth Report, App. IV., pp. 1–9.
[†] From N/8 permanganate at 27° C. (80° F.).
[‡] (*a*) First Series; (*b*) Second Series.

TABLE IV.

Average Samples of Series I., Drawn March and April, 1911.

Parts per 100,000.

	Ammoniacal + organic nitrogen.	Oxygen absorbed from N/8 permanganate at 27° C. (80°F.)		Ratio of "oxygen absorbed" at once : 4 hrs.	Dissolved oxygen taken up from water at 18° C. (65° F.)		Ratio of dissolved oxygen taken up in 48 hrs. : 5 days.	Dissolved Oxygen taken up in long aeration (after correcting for gas at top of bottle).[4]	Number of days sample was kept aerated.	Dilution (volumes of tap water used).	Ratio of dissolved oxygen taken up in 5 days to oxygen taken up in long aeration.	Solids in suspension.	Volatile matter in these solids.	"Strength" multiple for oxygen absorbed in 4 hrs.[3]
		At once.	In 4 hrs.		In 48 hrs.	In 5 days.								
Nature of Sample.														
Brewery Waste:														
No. 1 - -	4·43	4·40	51·19	1 : 11·6	34·9[1]	71·6	1 : 2·1	248·4	559	699	1 : 3·5	50·3	44·6	4·46
„ 9 - -	7·74	5·45	79·07	1 : 14·5	35·5	192·0 + x[2]	1 : 5·4*	360·7	560	699	1 : 1·9†	81·0	70·4	4·13
„ 13 - -	4·90	5·74	69·0	1 : 12·0	82·6	131·6	1 : 1·6	324·6	577	699	1 : 2·5	49·7	43·8	4·39
Average -	5·69	5·20	66·42	1 : 12·7	51·0	131·7	1 : 3·0	311·2	—	—	1 : 2·6	60·3	52·9	4·32
Mixed Sewage and Brewery Waste														
No. 2 - -	7·39	4·61	36·69	1 : 8·0	40·9[1]	87·4	1 : 2·1	256·4	559	599	1 : 2·9	44·3	38·9	6·08
„ 10 - -	10·87	6·87	67·07	1 : 9·8	88·0 + x	156·6	1 : 1·8 †	423·4	568	599	1 : 2·7	96·3	85·7	5·58
„ 14 - -	5·21	4·59	50·74	1 : 11·0	84·0 + x	120·4	1 : 1·4 †	314·2	577	599	1 : 2·6	41·3	37·0	5·73
Average -	7·82	5·36	51·49	1 : 9·6	71 + x	121·5	1 : 1·8 †	331·3	—	—	1 : 2·7	60·6	53·9	5·80
Septic Tank Liquor.														
No. 3 - -	9·59	3·32	13·89	1 : 4·2	28·7[1]	60·0	1 : 2·1	156·7	562	299	1 : 2·6	18·4	15·7	8·17
„ 11 - -	8·75	2·87	12·16	1 : 4·2	26·8	49·2	1 : 1·8	151·5	568	299	1 : 3·1	14·9	10·7	9·22
„ 15 - -	8·48	2·56	9·96	1 : 3·9	29·3	48·8	1 : 1·7	173·2	585	299	1 : 3·5	29·1	23·9	13·56
Average -	8·94	2·92	12·00	1 : 4·1	28·3	52·7	1 : 1·9	160·5	—	—	1 : 3·1	20·8	16·8	10·32
			Further Average Samples of Series I.											
Brewery Waste.														
No. 17 - -					57·7	110·4								
„ 21 - -					100·9 + x	168·2								
„ 26 - -					80·9	118·5								
„ 30 - -					114·5	203·4								
			Average - -		88·5	150·1								
Mixed Sewage and Brewery Waste.														
No. 18 - -					57·7	105·0								
„ 22 - -					84·0	121·2								
„ 27 - -					60·0	115·0								
„ 31 - -					133 + x	192·6								
			Average - -		83·9	133·5								
Septic Tank Liquor.														
No. 19 - -					26·3	47·4								
„ 23 - -					26·0	36·4								
„ 28 - -					30·8	75·3								

Notes.

1. Two-thirds of three days.

2. " + x " means that the oxygen present was exhausted.

3. According to the formula:—
(Ammon + organic N) x 4·5 + ox. abs. in 4 hours x ?
cf. Fifth Report, App. IV., pp. 1–9.

4. The figures without the gas corrections were:—

No. 1 -	327·6	No. 2 -	315·6	No. 3 -	193·5
„ 9 -	413·7	„ 10 -	439·2	„ 11 -	173·7
„ 13 -	359·8	„ 14 -	343·8	„ 15 -	189·6

* A ratio of 1 : something more than 5·4.
† A ratio of 1 : something less than 1·8; and so on.

IV.—THE DETERMINATION OF SUSPENDED SOLIDS IN VARIOUS TYPES OF TRADE EFFLUENT, KEPT FOR ONE, TWO AND FOUR DAYS, BY DR. G. McGOWAN.

In view of the importance of keeping the suspended solids of trade effluents—as discharged—as low as possible, and also of the circumstance that, in the present state of knowledge, nothing beyond a suspended solids standard seems reasonable to ask for in certain cases, it became desirable to ascertain whether the suspended solids of different trade wastes increased materially by the deposition of colloidal matter, on keeping samples for 24 and 28 hours at laboratory temperature and then for a further 48 hours in the ice-box.

In the Appendix to the Eighth Report, pp. 155–173, under the heading, "The Collection of Samples for Standard Purposes," this question is examined with regard to sewage liquors and effluents. On pp. 172–173 recommendations are made as to the interval which might be allowed to elapse between the actual drawing of a sample and the determination of its suspended solids, seeing that it is impracticable in the case of most samples to make such estimation at the moment they are drawn.

Briefly, the recommendation was that the suspended solids in a sewage liquor or effluent should not be estimated until 48 hours after the time of drawing, the sample meanwhile to be kept in a full bottle at air or laboratory temperature; further, if this 48 hours' period terminated outside ordinary working hours, then the sample was to be put in the ice-box and kept there until next morning, or, if necessary, for a period not exceeding 48 hours.

We have recently examined a number of samples, in triplicate, of various trade effluents in this connection, the estimation of the suspended solids being made by Mr. G. T. P. Tatham, by filtration through asbestos in a Gooch crucible, as detailed in the Appendix to the Eighth Report, pp. 103–109. The samples were drawn for the Commission by the various works authorities, to whom we would express our thanks for their kind help in the matter. Since it was all-important that the three bottles (half-Winchester quart bottles) constituting one sample should be identical as regards liquid and solid content, definite instructions had to be given as to how the sample was to be taken. We, therefore, reproduce here the letter sent to each works in turn, which shows how this was accomplished.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

Chemical Laboratory,
30, High Street,
Ealing, London, W.

Dear Sir,—The Commission are at present making some observations on the effect of keeping samples of trade waste effluents of different kinds for two or three days, in order to see how far they throw down colloidal or other matter.

We should be much indebted to you if you would kindly let us have what you consider a fairly average sample of your *final effluent* for this purpose, and I am, therefore, sending a basket containing three bottles.

If you would fill all three of these bottles with exactly the same sample of effluent and return it to me by passenger train, carriage forward, I should be greatly obliged.

It is essential, for the purposes of the experiments, that the samples (liquid and solid together) in the three bottles should be identical in composition.

The best way to ensure this will be to fill a *large clean* pail with the effluent, and stir this with a clean smooth stick for *two minutes*, so as to disseminate the solids equally through the liquid. Then, while one person continues to stir quietly, another should dip a small glass measure into the pail and pour the contents quickly into the first bottle A; then the same with bottles B and C, before returning to pour a second glassful into A., and so on.

If a very large glass were taken, some solids might deposit in it before all its contents could be transferred to the bottle, and in this case the samples in the bottles would be no longer uniform.

It is also necessary to fill the bottles completely full of effluent. The effluent should be poured into each bottle until it overflows. Then, after the lapse of a minute or so, to allow small bubbles to rise up through the neck of the bottle, the stopper should be gently dropped into the water filling the neck and given a slight turn to make tight. When the bottle is stoppered, it should be turned upside down to see that no air bubble remains enclosed.

It would be well to draw the sample between 10 and 11 o'clock on the morning of   , and to despatch the basket not later than the *afternoon of the same day*. In this way the samples would reach Ealing early on the following morning.

A key for the sample basket is enclosed herewith (which please return), and also a label for noting down what the sample is and the day and hour of sampling.

With apologies for giving you so much trouble,

Yours faithfully,

(*Signed*) George McGowan.

Table I. gives the figures for suspended solids in the trade effluents, determined:—

(1) From a full bottle, A, kept at air temperature, about 24 hours after drawing (the limits of time were 20 hours and 30 hours).

(2) From the same bottle, A, kept at air temperature, which had been shaken up after the first estimation and partly emptied, to allow of further aeration—24 hours later, *i.e.*, about 48 hours after the sample was drawn (the limits of time were in this case 44 and 53 hours).

(3) From a full bottle, B, kept at air temperature (the limits of time in this case were 43 and 54 hours).

(4) From a full bottle, C, kept at air temperature for 48 hours after drawing and then for a further 48 hours in the ice-box. In one or two cases, as noted in the Table, the period in the ice-box was longer than this.

In these estimations of suspended solids there are a number of discrepancies or apparent discrepancies. The estimations must, however, not be regarded too strictly, as they were more or less of a preliminary character and were subject to several possible sources of error. Thus, the samples (consisting of 3 bottles each) were drawn by different people. Again, it was not always easy at the laboratory to know how much of a particular sample should be taken for an estimation—at all events for the first estimation of a series.

It would probably be well always to have in hand some prepared (but unweighed) Gooch crucibles, so that a preliminary trial might be made and in this way the proper quantity to be taken for an estimation fairly well gauged.

Subject to what has just been said, the figures in the Table appear to indicate that—with the exception of the Brown Paper Works effluent and perhaps also the fellmongering soak liquor—there was little tendency, in the various types of effluent tested, for colloidal matter to come down, with corresponding increase of suspended matter, *within the limits of time allowed between the drawing of the sample and the analysis.* (All, or practically all, trade effluents do clear themselves, if kept for a sufficient length of time in a bottle containing excess of air).

Further, in the case of the samples containing about 5 parts suspended solids or less, the results are on the whole very concordant for each set of samples. The difficulties of accurate sub-sampling and estimation of suspended solids are more marked with colloidal liquids holding considerable solid in suspension.

The necessity for further work on the subject has already been adverted to, but we would suggest,* in the meantime :—

(1) That the recommendations made in the Appendix to the Eighth Report, pp. 172–173, with regard to the length of time to be allowed between the drawing and the analysis of a sewage liquor or effluent be applied to trade waste effluents also.

(2) That before actually carrying out an estimation of suspended solids upon a trade waste effluent of unknown quality, a preliminary filtration should be made through an unweighed but otherwise prepared Gooch filter.

(3) That, wherever possible (*i.e.*, for samples containing apparently about 6 parts or less of suspended solids per 100,000), 200 c.c. should be poured rapidly, and in several fractions, from the well-shaken sample bottle into a 200 c.c. measuring flask, and allowed to stand in this for two hours before the filtration through the Gooch crucible is begun.

(4) When the sample contains apparently about 9 or 12 parts suspended solids, then 150 or 100 c.c. should be poured out into measuring flasks of those sizes in the same way, and also allowed to stand for two hours.

(5) When—either through the colloidal character of the trade waste or the large amount of suspended solids in it—quantities of less than 100 c.c. have to be taken for an estimation, probably the best plan will be to pipette out 50 c.c., or 25 + 50 c.c. rapidly, from the middle of the sample bottle, transfer the contents of the pipette to a small beaker, wash out the pipette or pipettes with a few c.c. of water, and let the whole stand for two hours before filtration. Further systematic work is, however, required before it can be stated definitely what is the best method of getting a true small measured sample of a given trade effluent for the Gooch filtration.

George McGowan.

June, 1914.

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* This suggestion is made from Mr. Colin C. Frye, Mr. G. B. Kershaw and myself.

TABLE I.

Determination of Suspended Solids in Trade Effluents.

Type of Works.	Works Number.	Nature of Sample and Date of Drawing.	Suspended Solids after 24 hours. From Bottle A (full).	Appearance of Filtrate.	Suspended Solids after 48 hours. From Bottle A (partly full).	Appearance of Filtrate.	Suspended Solids after 48 hours. From Bottle B (full).	Appearance of Filtrate.	Suspended Solids after 96 hours. (Sample in ice for the last 48 hours.) From Bottle C (full).	Appearance of Filtrate.	NOTES.
Paper - - - - -	No. 35.	Percolating Filter Effluent. Thursday, Oct. 30th, 1913, 12.15 noon.	—	—	§ [1]13·2 { 8·2 V. 5.0 N.	Not noted.	‡11·9 { 6·7 V. 5·2 N.	Cloudy. No weighable precipitate came down, however, in 48 hours.	§12·4 { 8·2 V. 4·2 N.	Not noted.	[1] This estimation was done from a bottle which had stood full for 48 hours, and then half full for another 48 hours. Only two bottles of this sample were received.
Paper - - - - -	No. 35.	Percolating Filter Effluent. Monday, Nov. 10th, 1913, 4.15 p.m.	§ 8·2 { 6·4 V. 1·8 N.	Somewhat cloudy.	§ 8·6 { 6·4 V. 2·2 N.	Somewhat cloudy.	§ 4·8 { 3·2 V. 1·6 N.	Rather cloudy.	§ 6·2 { 5·2 V. 1·0 N.	Rather cloudy.	Only two bottles of this sample were received. The contents of these were mixed on Nov. 11th, and subsequently divided again.
Paper - - - - -	No. 35.	Percolating Filter Effluent. Wednesday, Feb. 4th, 1914, 12.45 noon.	‡ 6·0 { 3·6 V. 2·4 N.	Cloudy.	‡ 8·0 { 4·8 V. 3·2 N.	Rather less cloudy than yesterday's filtrate.	‡ 8·7 { 5·5 V. 3·2 N.	Rather less cloudy than yesterday's filtrate.	‡ 5·9 { 3·9 V. 2·0 N. (5 days in ice.)	Cloudy.	When drawn, this sample was brownish and opalescent, with a strong kier smell.
Paper - - - - -	No. 37.	Final Effluent. Wednesday, Nov. 19th, 1913, 10.45 a.m.	‡19·2 { 8·2 V. 11·0 N.	Clear and bright.	‡19·7 { 8·7 V. 11·0 N.	Clear and bright.	‡19·8 { 8 9 V. 10·9 N.	Clear.	‡21·9 { 8 9 V. 13·0 N. (4 days in ice.)	Clear and bright.	
Brown Paper - - -	No. 40.	Effluent. Tuesday, Jan. 6th, 1914, 2.30 p.m.	*13·1 { 6·3 V. 6·8 N.	Opalescent and brown.	*17·2 { 7·3 V. 9·9 N.	Brown, but clear.	†16·3 { 7·1 V. 9·2 N.	Slightly opalescent.	†17·1 { 7·6 V. 9·5 N.	Very slightly opalescent.	
Bleach - - - - -	No. 15.	Final Effluent. Tuesday, Nov. 18th, 1913, 12 noon.	‡34·0 { 15·4 V. 18·6 N.	Cloudy.	‡26·5 { 13·1 V. 13·4 N.	Cloudy.	§32·0 { 17·0 V. 15·0 N.	Cloudy. Filtration very slow.	‡32·8 { 16·9 V. 15·9 N.	Cloudy and yellowish. Filtration very slow.	
Bleach - - - -	No. 15.	Final Effluent. Tuesday, Dec. 16th, 1913, 12 noon.	§27·4 { 10·4 V. 17·0 N.	Cloudy.	§41·2 { 17·8 V. 23·4 N.	Somewhat cloudy.	§26·6 { 10·8 V. 15·8 N.	More cloudy than preceding filtrate.	§35·2 { 16·0 V. 19·2 N.	Cloudy.	
Bleach - - - - - -	No. 16.	Effluent. Tuesday, Jan. 27th, 1914, 10.45 a.m.	†14·8 { 3·9 V. 10·9 N.	Cloudy.	†14·5 { 4·4 V. 10·1 N.	Cloudy.	†14·8 { 4·2 V. 10·6 N.	Cloudy.	†16·4 { 6·2 V. 10·2 N.	Cloudy.	
Brewery - - - -	No. 52.	Secondary Contact Effluent. Wednesday, Nov. 19th, 1913, 12.30 to 1.30 noon.	‖ 4·5 { 3·6 V. 0·9 N.	Very slightly cloudy.	‖ 5·1 { 4·1 V. 1·0 N.	Rather cloudy.	‖ 4·8 { 4·2 V. 0·6 N.	Rather cloudy.	‖ 3·7 { 3·0 V. 0·7 N. (3 days in ice.)	Rather cloudy.	
Fellmongery - -	No. 59.	Effluent (*i.e.*, tank liquor, derived from soak water alone). Thursday, Dec. 11th, 1913, 11.30 a.m.	† 7·3 { 4·2 V. 3·1 N.	Nearly clear.	‖ 7·9 { 4·8 V. 3·1 N.	Clear.	‖ [2] 9·0 { 5·3 V. 3·7 N.	Clear. Filtration very slow.	‖ 10·0 { 5·5 V. 4·5 N.	Clear. Filtration easy.	[2] This estimation was done on a small bottle, filled from Bottle A, on Dec. 12th.
Chrome Tannery - -	No. 61.	Final Effluent. Thursday, Feb. 5th, 1914, 3 p.m.	†22·6 { 7·3 V. 15·3 N.	Yellow and cloudy.	†22·2 { 8·7 V. 13·5 N.	Yellow and cloudy. Filtration very slow.	†16·9 { 6·3 V. 10·6 N.	Yellow and cloudy.	‖ 25·7 { 7·2 V. 18·5 N.	Cloudy.	

* Means that 200 c.c. were taken for an estimation.
† Means that 150 c.c. were taken for an estimation.
‖ Means that 100 c.c. were taken for an estimation.
‡ Means that 75 c.c. were taken for an estimation.
§ Means that 50 c.c. were taken for an estimation.
"V" = Volatile on ignition.
"N" = Non-volatile on ignition.

(*To face page* 154).

TABLE I.—(*continued*).

DETERMINATION OF SUSPENDED SOLIDS IN TRADE EFFLUENTS.

Type of Works.	Works Number.	Nature of Sample and Date of Drawing.	Suspended Solids after 24 hours. From Bottle A (full).	Appearance of Filtrate.	Suspended Solids after 48 hours. From Bottle A (partly full).	Appearance of Filtrate.	Suspended Solids after 48 hours. From Bottle B (full).	Appearance of Filtrate.	Suspended Solids after 96 hours. (Sample in ice for the last 48 hours.) From Bottle C (full).	Appearance of Filtrate.	NOTES.
Dye and Print - - -	No. 7.	Final Effluent. Wednesday, Jan. 7th, 1914, 3 p.m.	* 3·7 { 1·7 V. 2·0 N.	Very slightly opalescent.	* 5·7 { 3·3 V. 2·4 N.	Very slightly opalescent.	* 3·7 { 1·6 V. 2·1 N.	Very slightly opalescent.	* 4·0 { 1·3 V. 2·7 N.	Very slightly opalescent.	
Dye and Print - - -	No. 11.	Final Effluent. Tuesday, Dec. 2nd, 1913, 10.30 a.m.	*15·1 { 12·6 V. 2·5 N.	Very cloudy.	*13·2 { 11·1 V. 2·1 N.	Very cloudy.	*13·3 { 11·3 V. 2·0 N.	Very cloudy.	†13·7 { 11·4 V. 2·3 N.	Very cloudy.	The filtrations in this case all went ve slowly towards the end. A furth portion was filtered on Dec. 4th, aft air had been bubbled through it f 5 hours on Dec. 3rd. This gave: Suspended Solids = 14·8 { 12·4 V. 2·4 N. The solids smelt strongly of oil, wh heated.
Dye and Print - - -	No. 11.	Final Effluent. Monday, Dec. 15th, 1913.	‖11·0 { 9·7 V. 1·3 N.	Cloudy.	‖11·8 { 10·4 V. 1·4 N.	Cloudy.	‖ 7·4 { 6·8 V. 0·6 N.	Cloudy.	‖11·1 { 8·9 V. 2·2 N.	Cloudy.	
Dye and Print - - -	No. 8.	Final Effluent. Wednesday, Nov. 26th, 1913, 10.55 a.m.	* 1·6 { 0·7 V. 0·9 N.	Quite clear.	* 1·7 { 0·7 V. 1·0 N.	Quite clear.	* 1·9 { 1·0 V. 0·9 N.	Quite clear.	* 1·9 { 0·9 V. 1·0 N. (3 days in ice.)	Quite clear.	
Dye and Print - - -	No. 12.	Final Effluent. Tuesday, Dec. 2nd, 1913, 10.30 a.m.	—	—	—	—	* 5·6 { 2·0 V. 3·6 N.	Quite clear.	* 4·5 { 2·1 V. 2·4 N.	Clear.	The second figure for suspended sol (4·5) is less than the true figure, some crystalline carbonate of li adhered to the bottle. Bottle B, nearly empty, after an ad tional 48 hours at air temperatu gave: Suspended Solids = 6·7 { 2·4 V. 4·3 N. These solids smelt strongly of oil, wh heated.
Dye and Print - - -	No. 12.	Crude Waste. Tuesday, Dec. 2nd, 1913, 10.30 a.m.	—	—	—	—	*23·1 { 11·7 V. 11·4 N.	Fairly Clear.	—	—	This filtration was very difficult, owi to colloidal matter, and took about hours, although the measured sam had had a preliminary settlement 2 hours before being poured into Gooch crucible.
Dye and Print - - -	No. 12A.	Final Effluent. Tuesday, Nov. 11th, 1913, 11.30 a.m.	* 6·5 { 4·4 V. 2·1 N.	Somewhat cloudy.	* 9·2 { 5·6 V. 3·6 N.	Somewhat cloudy.	§10·0 { 7·4 V. 2·6 N.	Slightly cloudy. Filtration very slow.	* 9·0 { 4·6 V. 4·4 N.	—	There were only two bottles of t sample originally. The contents w therefore mixed and divided amo three bottles on Nov. 12th, the th bottle being a small one.
Woollen Dye Works - -	No. 17.	Treated Effluent. Wednesday, Jan. 14th, 1914, 12.15 noon.	* 2·3 { 1·4 V. 0·9 N.	Almost clear, but yellowish.	* 2·5 { 1·4 V. 1·1 N.	Almost clear.	* 2·1 { 1·0 V. 1·1 N.	Almost clear.	* 2·5 { 0·8 V. 1·7 N. (5 days in ice.)	Clear.	
Woollen Dye Works - -	No. 0.	Effluent. Tuesday, Jan. 20th, 1914, 10.15 a.m.	* 2·3 { 2·0 V. 0·3 N.	Clear, but dark.	* 2·3 { 1·8 V. 0·5 N.	Clear, etc.	* 2·4 { 2·0 V. 0·4 N.	Clear, etc.	* 2·6 { 2·2 V. 0·4 N.	Clear, but dark.	
Wool-scouring and Dye Works	No. 30.	Average Effluent. Tuesday, Jan. 20th, 1914, 9.30 a.m. to 3.0 p.m.	* 2·3 { 1·0 V. 1·3 N.	Clear, but yellowish.	* 2·3 { 0·6 V. 1·7 N.	Clear, etc.	* 2·0 { 0·7 V. 1·3 N.	Clear, etc.	* 2·3 { 0·9 V. 1·4 N.	Clear, but yellowish.	
Piece-scouring Works - -	No. 23.	Effluent. Monday, Jan. 12th, 1914.	‖ 4·2 { 2·9 V. 1·3 N.	Clear.	‖ 4·3 { 3·2 V. 1·1 N.	Clear.	‖ 5·3 { 3·9 V. 1·4 N.	Clear.	‖ 4·1 { 3·3 V. 0·8 N.	Clear.	

* Means that 200 c.c. were taken for an estimation.
† Means that 150 c.c. were taken for an estimation.
‖ Means that 100 c.c. were taken for an estimation.
‡ Means that 75 c.c. were taken for an estimation.
§ Means that 50 c.c. were taken for an estimation.
"V" = Volatile on ignition.
"N" = Non-Volatile on ignition

V.—SUPPLEMENTARY NOTE ON THE METHODS OF ANALYSIS FOR SEWAGE LIQUORS AND EFFLUENTS FOLLOWED IN THE WORK OF THE COMMISSION, BY DR. G. McGOWAN.

In one of the Appendices to the Fourth Report (Vol. IV., Part V., 1904), by Dr. G. McGowan, Mr. R. B. Floris, and Mr. R. S. Finlow, the methods of analysis followed up to that date, together with some addenda bearing on the subject, were detailed. These methods have continued to be used, as a whole, but with added experience some modifications and additions have been made to them, and the more important of these changes may now be very shortly referred to.

Vol. IV., Part V., p. 9. *Sampling of Sewages and Effluents, etc.*

This is now supplemented by Section 9 of the Appendix to the Eighth Report, 1913, pp. 155–173.

Page 11. "*Jointing*" *of samples.*

Supplemented by part of Section 8 of Appendix to Eighth Report, p. 149 (including note on that page).

Pages 11–14. *Determination of* (A) *Free and Saline Ammonia, and* (B) Albuminoid Ammonia.

The use here of distilled water prepared from a continuous-feed copper still has long been discontinued, as explained in the note by myself in the Preface to Appendix III. of the Fifth Report, pp. iii.–iv. (1909). Instead of such water, water slightly acidified with sulphuric aid and then distilled from a glass flask is employed. The large round-bottomed stoppered flasks used in the determination of the Free and Albuminoid ammonia should have the delivery tube high up the neck. Page 14.—The fractions collected for albuminoid ammonia are now (in the case of sewage liquors and effluents) 150 and 50 c.c., respectively, instead of 100, 50, and 50 c.c., as given in Vol. IV., Part V.

Page 17. *Estimation of Nitric and Nitrous nitrogen together by the Copper-Zinc Couple.*

The last paragraph of this page should now begin:—"(*a*) If the amount of ammoniacal nitrogen is comparatively small—say, not more than 0·2 part per 100,000, then 10 c.c. or less of the sample . . . ."

Page 23. *Nitrate: Approximate estimation of, by the Pyrogallic Acid method.*

This colorimetric method we have often found very useful and time-saving, when an approximate estimation only of nitrate was required—say, to within 0·25 part Nitric nitrogen per 100,000.

In par 2, lines 6–7, it is recommended to use a small pipette, plugged at the upper end with a piece of cotton wool. Instead of this, we now use a pipette with a bulb near the top and a very small orifice at the lower end.

Page 24. *Kjeldahl process for the estimation of Total Nitrogen.*

If a determination of the total nitrogen in a sewage effluent is required in a hurry, a zinc-copper couple may be employed for the reduction instead of zinc foil. By this means the reduction is completed in one night. Under ordinary conditions, however, the slower reduction process is to be preferred.

Page 37, *second last paragraph.* "*Oxygen absorbed*" *from permanganate.*

For the measurement of the 10 c.c. of permanganate solution we have for long used a 3-way pipette—an idea due to Mr. A. F. Girvan. This can be relied upon to measure out practically identical quantities.

Page 40, *second last paragraph. The* 4-*hours test.*

It is advisable to gently rotate the bottle containing the mixture of effluent and permanganate one hour after it has been placed in the incubator. Mr. Joseph Clifford has shown that practically half the total absorption of oxygen by effluents from permanganate in 4 hours has taken place by the end of the first hour.

Page 44. *Solids in Suspension.*

The details of this gravimetric estimation are given in the Appendix to the Eighth Report, Section 3, pp. 103–109.

Page 55. *Dissolved Oxygen Absorption in* 5 *Days.*

This, too, is given in detail in the Appendix to the Eighth Report, pp. 93–102.

Trade Waste Effluents.

The methods of analysis followed in the chemical examination of the various trade waste effluents cited in the Ninth Report have been, as far as possible, the same as for sewage liquors and effluents; modifications, however, had frequently to be introduced, while supplementary methods had also to be made use of.

October, 1914. GEORGE McGOWAN.

VI.—THE MANURIAL VALUE OF NATURAL (DRIED) AND OF DE-GREASED SEWAGE SLUDGE, BY DR. J. A. VOELCKER.

In the season 1906–7, experiments were carried out, on behalf of the Royal Commission on Sewage Disposal, at the Woburn Experimental Station of the Royal Agricultural Society of England. The account of these experiments is recorded in Appendices VIII. and IV. of the Fifth Report of the Commission.

The experiments resolved themselves into a comparison of seven different kinds of sewage sludge which were submitted, and to seeing how these succeeded in relation to artificial manurings containing approximately like ingredients. The experiments were conducted by means of pot-culture trials on wheat, and the general result was to show that those sludges did best which contained the most moisture and the most lime, but that high amounts of organic matter and of total nitrogen did not produce a correspondingly good result, while all the sludges alike were somewhat inferior to artificial manurings supplying equal amounts of approximately like ingredients. An increase of 10 to 12 per cent. in corn and in straw over the unmanured produce was, on the average, obtained, as against one of 16 to 17 per cent. with artificial manuring. Further, when the attempt was made to give a money value to the sludges, based on the produce obtained, it was found that no one of them could be put at a higher figure than 10s. a ton, taking the price as that which a farmer would find it worth his while to give for the sludge as delivered on his land.

Since that time other methods of dealing with sewage sludge have been devised, including one in which the sludge is treated for the removal and recovery of the grease. Grease or fat of any kind, it is well known, is of no value as a manure; and, further, it exercises a retarding influence in that it prevents the ready decomposition of the organic and nitrogenous matters with which it may be mixed.

It was thought well to ascertain by direct experiment how far this method of "de-greasing" was successful in enhancing the value of the sewage sludge produced, and, being requested to conduct such an enquiry, I readily consented and now present the report on the work done.

The experiments, like the earlier ones, were carried out at the Woburn Pot-Culture Station, in the season 1913–4, and were upon the same sewage sludge, excepting that in one case the natural, untreated, sludge was used, and in the other the same sludge after being subjected to the "de-greasing" process.

The two lots of sludge were received at the Woburn Farm (Woburn, Beds.) on December 24th, 1913. Samples were drawn from the different bags and analysed, the results being as follows :—

	Natural sludge.	De-greased sludge.
	Per cent.	Per cent.
Moisture	17·88	8·29
Organic and volatile matters	35·12	34·06
Oxide of iron and alumina	7·56	9·86
Lime	2·49	3·02
Phosphoric acid	0·69	0·64
Magnesia, alkalies, etc.	3·06	4·58
Insoluble siliceous matter	33·20	39·55
	100·00	100·00
Total nitrogen	2·01	1·77
Equal to ammonia	2·44	2·15
Nitrogen soluble in water	0·317	0·156
Matters extractible by ether	7·58	1·96

It will be noted that there is a great difference between the two sludges in the matter of moisture, the natural having nearly 18 per cent., the de-greased only 8¼ per cent. Despite this, the natural sludge had not only the more nitrogen, but the more soluble nitrogen, the effect of the de-greasing or the additional drying clearly being to remove some of the nitrogen contained. While the natural sludge gave approximately 7½ per cent. of "grease," the treated sludge had under 2 per cent. At the same time the "de-greased" sludge was in a finer state of division and more friable. How far the organic matter was in each case affected is open to question, and it is quite possible that the greater extent to which the "de-greased" sludge was dried was responsible for the organic matter in it not breaking up so readily as in the moister natural sludge.

On reckoning out the amount of nitrogen which would be supplied in dressings of the sludges, it was found that with the "de-greased" sludge an application of 1 ton per acre would give 40 lbs. of nitrogen, while 1 ton per acre of the natural sludge would supply about 45 lbs. This quantity of 1 ton per acre was what previous experiments with sludges had told us would be sufficient to show an effect over unmanured lots, and, moreover, would be about that quantity which a farmer would be disposed to put on his land. In the neighbourhood of a sewage works a much larger proportion of sludge per acre could of course be economically applied.

The soil employed was that from one of the fields of the Woburn farm, a light, sandy loam, deficient in lime. Because of the latter feature it was decided to bring in a set in which lime alone was used. The full scheme of experiment resolved on was as follows, each experiment being conducted in pots, on wheat, and each in duplicate :—

Nos. 1 and 2 :	Untreated.
Nos. 3 and 4 :	Natural sludge—1 ton per acre.
Nos. 5 and 6 :	,, ,, —2 tons ,,
Nos. 7 and 8 :	,, ,, —1 ton per acre with ½ ton lime per acre.
Nos. 9 and 10 :	De-greased sludge—1 ton per acre.
Nos. 11 and 12 :	,, ,, —2 tons ,,
Nos. 13 and 14 :	,, ,, —1 ton per acre with ½ ton lime per acre
Nos. 15 and 16 :	Lime only—½ ton per acre.

Each pot had a layer of gravel at the bottom and held additionally about 34 lbs. of soil. The sludge applications were mixed with dry soil and this was worked well into the top 2 inches of soil, thus representing, in practice, a top-dressing turned in. This was done on January 14th, 1914, and wheat was sown the following day (January 15th), twelve seeds in each pot.

Germination took place quite well and regularly, and there were no differences of note in respect of this. The wheat plants came up well, and on March 18th were reduced by "thinning" to six in each pot. By April 20th the dressing of 2 tons per acre of the natural sludge (pots 5 and 6) showed a slight superiority to the others. The most backward were the "untreated" and the "lime only" pots.

The wheat came into ear about June 12th, and the crops went on well, retaining the respective appearances noted above, more or less. They were photographed on August 11th, and measurements of the length of straw and of length of ear were made then. The straw of the "natural" sludge then appeared brighter and the ears better formed than with the "de-greased" sludge.

The plants ripened off well and the crop was cut on August 13th, the grain being subsequently beaten out and the corn and straw weighed. The following are the full results obtained :—

Pots.	Treatment.	Corn.						Straw.			
		Average length of ear.		Number of grains.		Weight.		Average length of straw.		Weight.	
		Inches.	Percentage of untreated.		Percentage of untreated.	Grammes.	Percentage of untreated.	Inches.	Percentage of untreated.	Grammes.	Percentage of untreated.
1 and 2	Untreated - - -	2·68	100	526	100	18·70	100	29·1	100	38·27	100
3 and 4	Natural sludge—1 ton per acre - - - - -	2·61	98	590	112	22·92	122	31·0	106	39·36	102
5 and 6	Natural sludge—2 tons per acre - - - - -	2·61	98	585	111	22·58	120	33·3	114	43·00	112
7 and 8	Natural sludge—1 ton per acre with ½ ton lime per acre - - - - -	2·74	102	626	119	24·71	132	32·9	113	42·31	110
9 and 10	"De-greased" sludge—1 ton per acre - - -	2·48	93	541	102	18·89	101	28·4	98	40·95	107
1 and 12	"De-greased" sludge—2 tons per acre - -	2·61	97	592	112	22·08	118	29·7	102	40·36	102
3 and 14	"De-greased" sludge—1 ton per acre with ½ ton lime per acre - -	2·62	97	622	118	22·91	122	30·5	105	42·62	111
5 and 16	Lime only—½ ton per acre	2·56	95	563	107	21·18	113	28·7	99	39·11	102

The first point to note in these results is that the sludges generally gave an increase over the untreated produce. This gain was more marked in the corn than in the straw, for, while the increase in weight of straw varied from 2 to 12 per cent., that in weight of corn was from 1 per cent. to as much as 32 per cent. The general average gain was 7·3 per cent. in straw and 19·2 per cent. in corn. The ears themselves were not longer with the treated lots, but they were better filled; the straw also was rather longer in the case of the treated sets.

The main interest turns on the question whether the "de-greasing" exercised a beneficial influence or not. Examination of the figures will show that in no case did the de-greased sludge give more corn than the natural sludge, nor was the length of straw increased. The average increase in grain, over the untreated produce, was 25 per cent. with the natural sludge and 14 per cent. with the de-greased.

There would appear, therefore, to be no advantage, from a manurial point of view, but rather the reverse, in the "de-greasing" process. Whether this is to be attributed directly to the process, or whether to the fact that the "de-greased" sludge was so much drier than the natural one and also contained less nitrogen, is open to question, but it will be remembered that in the earlier experiments of 1906–7, it was found that the sludges that were not highly dried did the best, possibly owing to the more ready decomposability of their organic matters.

It may also be the case that the "de-greasing" process has had the effect of interfering with the bacterial decomposition of the organic and nitrogenous matters, thus neutralising the benefit that might be expected to accrue from the removal of the fatty matters.

The best results were obtained by the use of sludge—whether natural or de-greased—along with lime, but that this was not due to the lime alone is shown from pots 15 and 16. One ton per acre of the natural sludge used alone did considerably better than a corresponding 1 ton of the "de-greased"; but between the 2 tons per acre application of each the difference was small, the one ton per acre of natural sludge along with lime doing, however, rather better than a similar application of "de-greased" sludge with lime.

J. Augustus Voelcker.

October 12*th*, 1914.

VII.—COMPARATIVE FIELD TRIALS WITH DRIED AND DE-GREASED SEWAGE SLUDGES AT ROTHAMSTED, BY Dr. E. J. RUSSELL AND Mr. E. H. RICHARDS, B.Sc.

The experiments here described were carried out at the Rothamsted Experimental Station at the request of the Royal Commission on Sewage Disposal. In 1905–7, an extensive series of field trials were made for the Commission at various stations, including Rothamsted, in order to compare the manurial value of typical sludges produced by the chief processes of sewage treatment with one another and with other manures; the results (Fifth Report of the Commission, Appendix VIII; also Appendix IV, pp. 78–83) were not at all encouraging. Since that date a new process of treatment has been introduced in which the greater part of the grease is removed from the sludge after drying. It is generally held that fatty matters have little or no manurial value in themselves, but may even exert a deleterious influence by impeding the decomposition of more valuable plant food; it was anticipated therefore that the de-greased sludge might yield better results than the original untreated but dried sludge. It should be added that both sludges were in a fine state of division.

These experiments were designed to ascertain what increase in crop an ordinary farmer might expect to obtain by the use of the sludges under normal farming conditions. In field trials of this kind the error of experiment is of the order of 10 per cent., so that smaller increases cannot be regarded as significant; at the same time the farmer would almost certainly fail to be convinced by anything less than crop increases of this magnitude.

The trials were carried out on two types of crop: (1) permanent grass for hay, and (2) oats. In the first case the land is not ploughed and the manure must be applied as a top dressing, while in the second the necessary cultivation allows the manure to be ploughed in and thoroughly incorporated with the soil.

The sludges were received in the latter part of December, 1913, and their nitrogen content was estimated on January 14th, 1914, and found to be:—

	No. 1. Dried sludge.	No. 2. De-greased sludge.
Nitrogen - - -	1·76 per cent.	1·55 per cent.

We did not ourselves analyse the sludges further, but Dr. McGowan has been good enough to send us his figures of analyses of samples from the bulk, drawn when the sludges were being despatched by Mr. C. C. Frye to Woburn and Rothamsted. He found:—

	No. 1. Dried sludge.*	No. 2. De-greased sludge.†
Sample drawn - - - - - - - - - -	Dec. 17th, 1913	Dec. 17th, 1913
Analysis begun - - - - - - - - - -	Dec. 19th, „	Dec. 19th, „
Moisture - - - - - - - - - - -	27·6 per cent.	7·0 per cent.
Dry matter - - - - - - - - - - -	72·4 „	93·0 „
	100·0 „	100·0 „
The dry matter gave:—		
Volatile on ignition - - - - - - - -	32·2 „	33·0 „
Non-Volatile - - - - - - - - - -	40·2 „	60·0 „
	70·4 „	93·0 „
Nitrogen - - - - - - - - - - - -	1·53 „	1·55 „
Nitrogen liberated as ammonia on distilling for half an hour with dilute solution of caustic potash (0·5 per cent. KOH), keeping volume of liquid constant - - - - - - (This was done on January 12th, 1914.)	0·17 „	0·16 „
Phosphoric Acid (P_2O_5) - - - - - - - - -	0·85 „	1·33 „
Matter extracted by ether, after drying *in vacuo* - - - -	8·55 „	1·57 „
Containing inorganic residue - - - - - - -	0·57 „	0·0 ,
Acidity, as H_2SO_4 (Methyl-orange) - - - - - - -	—	0·15 „
Alkalinity, as H_2SO_4 (Methyl-orange) - - - - - -	3·51 „	—

* This sample was an average of 15 sub-samples, taken in equal quantities from a large heap which had been dried on December 16th.

† This sample was an average of 15 sub-samples, taken in equal quantities from a large heap which had been prepared on December 13th and 14th.

G.M.

EXPERIMENT ON GRASS.

Five plots in Great Field, Rothamsted, of one-quarter to one acre each, were used for this trial. Of these, two were treated with sludge, one was left as a control, and two others were designed to show the effect of artificial nitrogenous manures under the same conditions. All the manures were applied on March 19th, 1914, at the uniform rate of 20 lbs. of nitrogen per acre (equivalent to about half a ton of sludge). The plots receiving sludge at no time showed any result from the application, but both of those treated with artificials showed up well by April 4th. March was a very wet month, but the rest of the season was distinctly dry. The crop was cut on June 30th and carted on July 4th. The results are recorded in Table I.:—

TABLE I.

Plots.	Area.	Actual weight of hay obtained.	Yield of hay per acre.
	acres.	cwt.	cwt.
Control - - - - -	0·25	4·41	17·64
No. 1 sludge (dried) - -	0·25	4·66	18·64
No. 2 sludge (dried and de-greased) - - -	0·25	4·07	16·29
Nitrolim* - - - -	1·00	21·59	21·59
Nitrate of soda - - -	0·25	6·48	25·93

* One of the new nitrogenous fertilizers, also known as calcium cyanamide.

It will be seen that the effects of the sludges are negligible. No. 1 (dried) gave 6 per cent. more than the control, while No. 2 (de-greased) gave 8 per cent. less. The failure is not due to the season, as Nitrolim and Nitrate of Soda yielded, respectively, 22 per cent. and 47 per cent. more than the control.

Experiment on Oats.

Five plots in Sawpit Field, each one-sixth of an acre in size, were sown with oats on October 2nd, 1913. On March 24th, 1914, two of these were dressed with the same sludges as were used for the grass experiment, and two were subsequently top-dressed with artificial nitrogenous manures at the uniform rate of 16·67 lbs. of nitrogen per acre. Neither of the plots receiving sludge showed any benefit while the crop was growing, but there was a considerable response to the artificial manures. The crop was cut on July 22nd, carted on August 4th, and threshed in October, 1914; it yielded the results given in Table II.:—

Table II.

Plots.	Quantities per acre:—					Weight per bushel of dressed grain (lbs.).
	Dressed grain (bushels).	Total grain (lbs.).	Total straw (lbs.).	Total straw (cwt.).	Total produce (lbs.).	
Control	41·27	1,833	2,207	19·7	4,040	43·8
No. 1 sludge	36·26	1,613	2,002	17·9	3,615	44·1
No. 2 sludge	37·39	1,679	2,136	19·1	3,815	44·5
Nitrolim	45·97	2,025	2,878	25·7	4,903	43·7
Nitrate of soda	44·14	1,941	2,767	24·7	4,708	43·6

As regards both grain and straw neither of the sludges gave so good a return as the control. The total produce from No. 1 (dried) sludge was 11 per cent. and from No. 2 (de-greased) was 6 per cent. less than that from the control plot. On the other hand, Nitrolim and Nitrate of Soda gave an increase in total produce of 21 per cent. and 17 per cent., respectively.

It is evident that the failure of the sludges is not due to season, as the other nitrogenous manures yielded good crops. Moreover, the soil is a heavy loam on which organic matter gives good returns.

The results of the two trials show that neither of the sludges gives any marked return; if any, it is less than 10 per cent. The trials of 1905–7 indicated that the nitrogen in sewage sludge is in a very stable combination which does not readily decompose under natural soil conditions. The present experiments lead to the same conclusion, and, moreover, they afford no evidence that the removal of the fat increases the ease of decomposition in the soil.

If there is a likelihood of a great quantity of such sludge being put on the market, it would be worth while to try the effect of the sludge in conjunction with more rapidly acting manures. This, however, would involve an extensive and costly series of trials, which could not be undertaken unless some definite benefit to agriculture was likely to accrue. Our experiments afford no evidence that either of the above sludges possesses any manurial value when used alone in quantities up to half a ton per acre.

E. J. Russell.

Eric H. Richards.

Rothamsted Experimental Station, Harpenden,
October 26th, 1914.

ADDENDUM.

The sludges actually used in the foregoing pot and field experiments at Woburn and Rothamsted were not examined bacteriologically. It will, however, be of interest to add here the figures of bacteriological analysis, by Dr. Houston, of two earlier samples of dried and de-greased sludge prepared at the same place and in the same way, together with a few notes by him. The chemical analysis of those earlier samples is also given, for purposes of comparison.

Bacteriological Analysis.

Samples drawn May 27th, 1913; analysed May 28th.

Results per gramme of material:—

	A. Dried sludge.	B. De-greased sludge.
Gelatine count	5,000,000	60,000
Agar count	3,800,000	1,000
Bile-salt-agar count	13,500 (all colourless)	None in 0·01
B. enteritidis sporogenes	+ 1 — 0·1	Neg. 1
B. coli (typical)	Neg. 1	Neg. 1

[The gelatin "count" estimates the total number of bacteria of all sorts, the agar "count" the microbes capable of growing at "blood heat." The bile-salt-agar "count" is nominally an estimation of excremental microbes, but includes bacteria less resistant than typical B. coli. The B. enteritidis sporogenes test gives some indication of the number of anærobic bacteria present in the form of spores. The typical B. coli test, in its negative aspects, affords assurance of the absence of the microbes of epidemic water-borne disease (*e.g.* B. typhosus.)]

It will be noted that the dried greasy (A) and de-greased (B) sludges yielded very different results.

Neither (A) nor (B) contained any typical B. coli in one gramme; but (A) yielded a very large "count" in bile-salt-agar of colourless colonies, whereas (B) contained none in 0·01 gramme. The gelatin and agar "counts" were very much higher in (A) than in (B).

From a manurial point of view, the chemical and physical condition of sludges is of paramount importance. The bacteriological condition would seem to be of minor importance, inasmuch as the soil on which the sludge is to be applied contains all the necessary bacteria for effecting the decomposition and nitrification of such constituents of the sludge as are not soluble and directly available for plant food, and are at the same time amenable to bacterial action.

A. C. Houston.

CHEMICAL ANALYSIS.

Samples drawn May 27th, 1913, and put in ice May 28th; analysis began June 9th.

	Parts per cent.	
	A. Dried sludge.	B. De-greased sludge.
Moisture	6·4	6·0
Dry matter	93·6	94·0
	100·0	100·0
The dry matter gave:—		
Volatile on ignition	33·9	35·8
Non-Volatile on ignition	59·7	58·2
	93·6	94·0
Grit, etc. (*i.e.*, matter insoluble in hydrochloric acid, ignited)	42·86	41·57
Oxide of iron and alumina ($Fe_2O_3 + Al_2O_3$), mostly iron	10·28	11·15
Lime (CaO)	1·58	1·54
Magnesia (MgO)	0·38	0·38
Nitrogen	1·36	1·43
Matter extracted by ether and dried *in vacuo* and then for half an hour at 105° C.	7·70	3·56
Containing inorganic residue	0·90	0·06

If this analysis of the de-greased sludge be compared with that of the sample drawn in December, 1913, it will be seen that the sample taken in May was not normal, containing as it did about half as much grease as the dried sludge.

The matter extractible by ether (and volatile on ignition) in the dried sludge diminished rather rapidly on keeping the latter, no doubt from bacterial action, whereas the de-greased sludge underwent no change in this respect in about three months. This is shown by the figures:—

Parts per cent. 1913.	Matter extractible by ether, volatile on ignition.	
	A. Dried sludge.	B. De-greased sludge.
June 10th	6·80*	3·50
July 9th	4·46	3·34
,, 16th	4·13	Not done
September 4th	3·51	3·38

* There is some doubt about this figure, which may possibly be rather too high.

The stability of the de-greased as compared with the dried sludge is further apparent from the following notes made on November 12th, 1914, on various samples which had been kept in bottles in the laboratory for a considerable time. The effect of the de-greasing process in preventing (or lessening the tendency of) the sludge to mould is at once apparent:—

Sample drawn.	Grease. (per cent.)	Appearance on November 12th, 1914.
A. Dried Sludge.		
May, 1913	6·8	Very mouldy on surface. (A small sub-sample showed little mould.)
December, 1913	8·0	Very mouldy in upper part of bottle.
B. De-greased Sludge.		
April, 1913	0·17	No mould.
May, 1913	3·3	No mould.
December, 1913	1·9	Some mould, but not very much.
December, 1913	1·5	No mould.

In both of the preceding papers emphasis is laid upon the resistant nature of the nitrogenous matter of sewage sludge, rendering the latter a poorer manure than its chemical composition would lead one to infer. The same point was brought out in the earlier manurial experiments done for the Commission in 1906–7. It would thus seem advisable that laboratory and other experiments should be carried on, with the object of ascertaining whether this nitrogenous matter might by some means or other be made more readily available as plant food.

GEORGE MCGOWAN.

November, 1914.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

FINAL REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(Including any Liquid from any Factory or Manufacturing Process)

MAY PROPERLY BE ADOPTED.

GENERAL SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE,
By WYMAN and SONS, Limited, 109, Fetter Lane, E.C.

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1915.

[Cd. 7821.] *Price 3d.*

THE ROYAL SANITARY INSTITUTE, FOUNDED 1876.
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Presented by

The Secretary

April 1915

VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath; Our Trusty and Well-beloved Sir Richard Thorne Thorne, Knight Commander of Our Most Honourable Order of the Bath, Medical Officer of the Local Government Board; Our Trusty and Well-beloved Constantine Phipps Carey, Esquire, Lieutenant-Colonel and Honorary Major-General on the Retired List of Our Army; Our Trusty and Well-beloved Charles Philip Cotton, Esquire; Our Trusty and Well-beloved Michael Foster, Esquire, Master of Arts, Professor of Physiology in Our University of Cambridge; Our Trusty and Well-beloved Thomas Walter Harding, Esquire, Retired Lieutenant-Colonel of Our Auxiliary Forces, with Honorary Rank of Colonel; Our Trusty and Well-beloved Thomas William Killick, Esquire; Our Trusty and Well-beloved William Ramsay, Esquire, Professor of Chemistry, University College, London; and Our Trusty and Well-beloved James Burn Russell, Esquire, Doctor of Medicine, Master of Surgery: Greeting!

Whereas We have deemed it expedient that a Commission should forthwith issue to inquire and report:

1. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory, or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities; and

   (2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage;

Now know ye, that We, reposing great trust and confidence in your knowledge and ability, have authorised and appointed, and do by these Presents authorise and appoint, you, the said Walter Stafford, Earl of Iddesleigh, Sir Richard Thorne Thorne, Constantine Phipps Carey, Charles Philip Cotton, Michael Foster, Thomas Walter Harding, Thomas William Killick, William Ramsay, and James Burn Russell to be Our Commissioners for the purposes of the said Inquiry.

And, for the better effecting the purposes of this, Our Commission, We do by these Presents give and grant unto you, or any three or more of you, full power to call before you such persons as you shall judge likely to afford you any information upon the subject of this Our Commission; and also to call for, have access to, and examine all such books, documents, registers, and records as may afford you the fullest information on the subject, and to inquire of and concerning the premises by all other lawful ways and means whatsoever.

And We do by these Presents authorise and empower you, or any three or more of you, to visit and personally inspect such places as you may deem it expedient so to inspect for the more effectual carrying out of the purposes aforesaid.

And We do further by these Presents will and ordain that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, and of every matter and thing therein contained, although the same be not continued from time to time by adjournment.

And We do further ordain that you, or any three or more of you, have liberty to report your proceedings under this Our Commission from time to time, if you shall judge it expedient so to do.

And Our further Will and Pleasure is that you do, with as little delay as possible, report to Us, under your hands and seals, or under the hands and seals of any three or more of you, your opinion upon the matters herein submitted for your consideration.

And for the purpose of aiding you in such matters, We hereby appoint Our Trusty and Well-beloved Frederick James Willis, Esquire, to be Secretary to this Our Commission.

Given at our Court at St. James's, the Seventh day of May, One thousand eight hundred and ninety-eight, in the Sixty-first Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. Ridley.

William Henry Power, Esq., F.R.S.,
To be a Member of the Royal Commission on Sewage Disposal.

VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith: To Our Right Trusty and Well-beloved William Henry Power, Esquire, Fellow of the Royal Society, Medical Officer of the Local Government Board: Greeting!

Whereas We did, by Warrant under Our Royal Sign Manual, bearing date the Seventh day of May, One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved cousin Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, or any three or more of them, to inquire into the treatment and disposal of sewage.

And whereas One of the Commissioners so appointed, namely, Sir Richard Thorne Thorne, has since deceased.

Now know ye, that We, reposing great confidence in you, do, by these Presents, appoint you, the said William Henry Power, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Sir Richard Thorne Thorne, deceased, in addition to, and together with, the other Commissioners whom we have already appointed.

Given at our Court at Saint James's, the Seventh day of February, One thousand nine hundred, in the Sixty-third Year of Our Reign.

By Her Majesty's Command,
(Signed) M. W. Ridley.

Whitehall, March 18th, 1901.

THE KING has been pleased to issue a Commission, under His Majesty's Royal Sign Manual, to the following effect :—

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland King, Defender of the Faith, to all to whom these Presents shall come, Greeting!

Whereas it pleased Her late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified :

And whereas, in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission ;
The Horse Breeding Commission ;
The Local Taxation Commission ;
The Port of London Commission ;
The Salmon Fisheries Commission ; and
The Sewage Disposal Commission ;

the Commissioners appointed by Her late Majesty, or such of them as were then acting as Commissioners, were, at the late demise of the Crown, still engaged upon the business entrusted to them :

And whereas, We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown :

Now know ye, that We, reposing great trust and confidence in the zeal, discretion, and ability of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissions do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration ; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the fourth day of March, One thousand nine hundred and one, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

THOMAS JOSEPH STAFFORD, F.R.C.S.I.
To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith. To Our Trusty and Well-beloved Thomas Joseph Stafford, Esquire, Fellow of the Royal College of Surgeons of Ireland, Medical Commissioner of the Local Government Board for Ireland : Greeting !

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, to be Commissioners to inquire into the treatment and disposal of Sewage.

And whereas, one of the Commissioners so appointed, namely, Our Trusty and Well-beloved Charles Philip Cotton, Esquire, hath humbly tendered unto Us his resignation of his appointment as one of the said Commissioners :

Now know ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Thomas Joseph Stafford, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Charles Philip Cotton, resigned, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of May, One thousand nine hundred and two, in the Second Year of Our Reign.

By His Majesty's Command,
(Signed) CHAS. T. RITCHIE.

REGINALD ARTHUR TATTON, ESQUIRE,
To be a Member of the Royal Commission on Sewage Disposal.

EDWARD R. & I.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith, To Our Trusty and Well-beloved Reginald Arthur Tatton, Esquire, Greeting !

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh Day of May, One thousand eight hundred and ninety-eight, appoint Commissioners to inquire into the treatment and disposal of Sewage.

And whereas, a vacancy has been caused in the body of the Commissioners appointed as aforesaid by the death of Major-General Constantine Phipps Carey, C.B.

Now know ye, that We, reposing great confidence in you, do by these Presents appoint you, the said Reginald Arthur Tatton, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Constantine Phipps Carey, deceased, in addition to and together with the present Members of the Commission.

Given at Our Court at Saint James's, the Seventh day of January, One thousand nine hundred and seven, in the Sixth Year of Our Reign.

By His Majesty's Command,
(Signed) H. J. GLADSTONE.

Whitehall, May 30th, 1910.

THE KING has been pleased to issue a Warrant under His Majesty's Royal Sign Manual to the following effect:—

GEORGE R. & I.

George the Fifth, by the Grace of God, of the United Kingdom of Great Britain and Ireland, and of the British Dominions beyond the Seas King, Defender of the Faith, to all to whom these Presents shall come. Greeting!

Whereas it pleased His late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified:

And whereas, in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission;
The Horse Breeding Commission;
The Sewage Disposal Commission;
The Poor Laws Commission;
The Tuberculosis Commission;
The Canal Communication Commission;
The Mines Commission;
The Welsh Church Commission;
The Coast Erosion and Afforestation Commission;
The Vivisection Commission;
The Land Transfer Acts Commission;
The Ancient Monuments (Wales and Monmouthshire) Commission;
The Ancient Monuments (England) Commission;
The Trade Relations between Canada and the West Indies Commission;
The Selection of Justices of the Peace Commission;
The Divorce and Matrimonial Causes Commission;
The University Education in London Commission; and
The Brussels, Rome and Turin Exhibitions Commission;

the Commissioners appointed by His late Majesty, or such of them as were then acting as Commissioners, were at the late demise of the Crown, still engaged upon the business entrusted to them:

And whereas, We deem it expedient that the said Commissioners should continue their labours in connection with the said enquiries notwithstanding the late demise of the Crown:

Now know ye, that We, reposing great trust and confidence in the zeal, discretion, and ability, of the present members of each of the said Commissions, do by these Presents authorise them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissioners do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents, shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the twenty-sixth
day of May, One thousand nine hundred and ten, in the
First Year of Our Reign.

By His Majesty's Command,
(Signed) R. B. HALDANE.

FREDERICK JAMES WILLIS, ESQ.,
To be a Member of the Royal Commission on Sewage Disposal.

GEORGE R. & I.

George the Fifth, by the Grace of God, of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas King, Defender of the Faith: To Our Trusty and Well-beloved Frederick James Willis, Esquire, Barrister-at-law, one of the Assistant Secretaries to the Local Government Board: Greeting!

Whereas Her late Majesty Queen Victoria did by Warrant under the Royal Sign Manual bearing date the Seventh day of May, One thousand eight hundred and ninety eight, appoint Commissioners to inquire into the treatment and disposal of Sewage:

Now know ye, that We, reposing great confidence in you do by these Presents appoint you the said Frederick James Willis, sometime Secretary to the said Royal Commission, to be an additional Commissioner for the purposes aforesaid.

Given at Our Court at Saint James's the Twentieth day of July, One thousand nine hundred and ten, in the First Year of Our Reign.

By His Majesty's Command,
(Signed) W. S. CHURCHILL.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

FINAL REPORT.

To The King's Most Excellent Majesty:

May it Please Your Majesty:

We, your Commissioners, appointed to inquire into the methods of disposing of sewage and trade effluents, humbly submit, as our Final Report, a general summary of the conclusions and recommendations contained in the nine Reports already submitted.

In this our Final Report we recapitulate briefly the main conclusions at which we have arrived as the result of an inquiry which has extended over a period of sixteen years.

Of the nine Reports which we have issued, four deal mainly with the purification of domestic sewage discharging into streams (Interim, Second, Fifth and Eighth Reports); two with the discharge of sewage into tidal waters (Fourth and Seventh Reports); and three with the discharge of manufacturing effluents (Third, Sixth and Ninth Reports).

Our Fourth, Sixth and Seventh Reports relate to investigations of a somewhat special nature, which we were requested to undertake with a view to suggesting solutions of particular problems which had arisen. We considered that the questions were of sufficient general importance as to warrant us in dealing with them as part of our inquiry.

The subject matter of our Fourth Report—the discharge of sewage into tidal waters—was brought specially to our notice by the Local Government Board, who had been moved to take action in consequence of a number of serious outbreaks of enteric fever, ascribed to the eating of shell-fish obtained from sewage-polluted water.

Following on our recommendations the shell fish owners agreed to close sewage-polluted layings, and oysters are in consequence far safer articles of diet than they were before the time of our inquiry. But our general recommendations for securing permanent and effective supervision and control, both of sewage outfalls and shell fish beds, have not yet been adopted.

Our Sixth Report was a special Report on the purification of distillery waste. The investigation of this question was pressed upon us by representatives of the Scottish malt distillery industry, who found themselves unable to comply with the demands made by riparian owners for the protection of the salmon fishery.

As the result of our experimental work, a plant was erected for the purification of distillery waste, which, during the past few years, has been proved capable of producing at reasonable cost an effluent which is not injurious to fish, and other similar plants are in process of erection.

The work in connection with our Seventh Report was undertaken at the request of the Local Government Board for Ireland.

A very serious nuisance, due to the decay of seaweed, had arisen in Belfast Lough, into which the sewage of Belfast was discharged. As it appeared that the growth of the weed was encouraged by sewage pollution, a costly scheme for the complete purification of Belfast sewage was submitted by the Corporation to the Local Government Board. Doubts having been expressed as to whether by these means the evil would be remedied and its occurrence prevented, the Local Government Board, knowing that we had had some evidence on the subject in connection with our inquiry into the pollution of tidal waters, desired to know whether we proposed to investigate further the best and least expensive means of treating sewage so as to avoid similar nuisances.

We considered the matter was one of sufficient general importance to justify us in making inquiry in regard to it.

We have recalled the particular circumstances in which these three Reports were written because they embodied the results of special investigations which, in the absence of a permanent authority for dealing with such questions, we felt bound to undertake. They form, however, an integral part of our general inquiry.

We append a summary of all our Reports in chronological sequence.

Interim Report. Cd. 685 [1901].

Our First Report was of an interim character, and contained the following conclusions:

(1) No land is entirely useless for purification of sewage, “but in the case of stiff clay and peat lands the power to purify sewage seems to depend on the depth of the top soil.”

“There are, of course, numerous gradations in the depths of the top soil which are met with in nature, and it is not easy to draw the line between lands which contain a sufficient depth to justify their use, and lands which do not.”

“We are, however, forced to conclude that peat and stiff clay lands are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of top soil is very small, say 6 inches or less, the area of such lands which would be required for efficient purification would in certain cases be so great as to render land treatment impracticable.”

(2) “. . . we are satisfied that it is practicable to produce by artificial processes alone either from sewage, or from certain mixtures of sewage and trade refuse, such, for example, as are met with at Leeds and Manchester, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance.”

“We think, therefore, that there are cases in which the Local Government Board would be justified in modifying, under proper safeguards, the present rule as regards the application of sewage to land.”

(3) “. . . as a result of a large number of examinations of effluents from sewage farms and from artificial processes we find that while in the case of effluents from land of a kind suitable for the purification of sewage there are fewer micro-organisms than in the effluents from most artificial processes, yet both classes of effluents usually contain large numbers of organisms, many of which appear to be of intestinal derivation, and some of which are of a kind liable, under certain circumstances at least, to give rise to disease.”

“We are of opinion, therefore, that such effluents must be regarded as potentially dangerous, and we are considering whether means are available and practicable for eliminating or destroying such organisms, or, at least, those giving rise to infectious diseases.”

(4) “It is of the utmost importance that the simplest possible means should be provided for adequately protecting all our rivers,” . . . and “it will be desirable, probably for some time to come, that scientific experiments should be carried on in order to ascertain all the real dangers of pollution, against which they should be protected.”

“In the present state of knowledge, and especially of bacteriology, it is difficult to estimate these dangers with any accuracy, and it seems quite possible that they should be either exaggerated or under-valued according to the pre-disposition of those who have to deal with them. An authority, guided by medical considerations, might not unnaturally be inclined to insist on a degree of purity which may ultimately prove in certain cases to be uncalled for, while another authority, with its mind fixed upon economy, might shrink from taking essential precautions.”

. . . “the general protection of our rivers is a matter of such grave concern as to demand the creation of a separate Commission, or a new department of the Local Government Board, which shall be a Supreme Rivers Authority, dealing with matters relating to rivers and their purification, and which, when appeal is made to them, shall have power to take action in cases where the local authorities have failed to do so.”

Second Report. Cd. 1178 [1902].

Our Second Report was a formal document covering certain scientific papers which were presented as an appendix to that Report.

Third Report. Cd. 1486 [1903].

In our Third Report we dealt with the relations between local authorities and manufacturers in regard to the disposal of manufacturing effluents. We found that the present state of the law was most unsatisfactory, that the attitude of local authorities towards manufacturers had differed widely, and that many manufacturers were seriously handicapped. Our investigations showed that purification of trade effluents by the local authority is in the great majority of cases practicable; purification by the manufacturer is in some cases difficult, if not impracticable; while purification by the manufacturer would generally be more costly than purification by the local authority.

It also appeared that the local authorities, as well as the manufacturers, were of opinion that there should be laid on the local authority a distinct obligation to receive trade effluents.

Our recommendations on this point were as follows:

“We are, therefore, of opinion that the law should be altered so as to make it the duty of the local authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and that the manufacturer should be given the right, subject to the observance of certain safeguards, to discharge trade effluents into the sewers of the local authority if he wishes to do so.”

“We do not think it possible to provide, by direct enactment, what these safeguards should be. In each district it would probably be desirable that the local authority should frame regulations which should be subject to confirmation by a Central Authority. In most cases, however, these regulations could provide definite standards for the different manufacturers as regards preliminary treatment, and it appears from the evidence that manufacturers would much prefer to have standards to work to.”

“Power to vary the standards or to dispense with them altogether in special cases would be necessary.”

“Although the duty of receiving trade effluents should, we think, be imposed on the local authority, cases may arise in which they should be wholly or partially relieved of it.”

“For example, we find that in some instances the effluent discharge from the manufactory is of a composite character, the greater part of which might with advantage be easily dealt with by the manufacturer if it were kept separate. In such cases we think the manufacturer would generally be willing to adopt this course, but provision is necessary for those cases in which the local authority and manufacturer could not agree.”

“Further, although we have received no conclusive evidence to show that there are trade effluents which could not be purified by the local authority, we do not deny the possibility of such cases arising.”

“And it is possible that in some cases, as, for example, of a large manufactory being newly established in a small district, it might be necessary to relieve the authority of the obligation to treat the trade effluent or to enable them to exact some special contribution from the manufacturer, not only for the cost of treatment, but also towards capital expenditure.”

“It is obvious, therefore, that some tribunal will be required for settling differences between the local authority and the manufacturer, and for relieving the local authority in exceptional cases, either wholly or partially, of their obligation to provide sewers and disposal works of sufficient capacity for trade effluents as well as ordinary sewage.”

“We are of opinion that generally no special charge should be made on the manufacturer in those cases in which the regulations as to preliminary treatment are complied with.”*

“As we have already stated, it is desirable that, wherever practicable, some preliminary treatment should be carried out by the manufacturer.”

“But where the manufacturer is unable to comply with these regulations we consider that the local authority should be empowered to make a special charge.”

“Power should also be granted to make a special charge, even when preliminary treatment is adopted, where there are exceptional circumstances as regards volume, quality or otherwise.”

Settlement of Differences between Local Authorities and Manufacturers.

The chief questions upon which we considered that differences might arise, were:

(1) The refusal of a local authority to allow a particular trade effluent to enter their sewers.
(2) The refusal of a local authority to construct or enlarge sewers for the purpose of a particular manufactory.
(3) The question of varying general regulations as to preliminary treatment by the manufacturer.
(4) The amount of the special charge to be imposed on the manufacturer.
(5) The removal of sludge.

The balance of opinion we found to be strongly in favour of the view that for the settlement of these questions it is necessary to constitute a Central Board possessing adequate technical knowledge, such as the Supreme Rivers Authority which we recommended in our Interim Report.

As regards this matter we reported as follows:

“We have been struck by the large sums which have been expended in appeals to Courts, but apart from the question of expense we are strongly of opinion that the ordinary Courts are not suitable for the determination of these questions, and we venture to think that the judgment of the Master of the Rolls in the case of Attorney-General *v.* Whitmore, to which we have already referred, clearly supports this view. His comment that ‘the evidence was very complicated, the expert witnesses who were called not only giving evidence quite inconsistent with one another, but some of them giving evidence in cross-examination which was quite inconsistent with what they said in examination in chief,’ might apply to many similar cases.”

“The scientific questions to be solved would in most instances be capable of actual determination by a properly-equipped Central Authority, and there can be little doubt that such direct proof would be far less costly than the process of endeavouring to arrive at the truth through the evidence of expert witnesses in a Court of Law.”

“Moreover, the matters to be determined include, not only scientific questions on which witnesses may be expected to differ, but also considerations of an administrative character which should more properly be dealt with by a Government Department.”

“Further, we find that a Central Authority possessing adequate technical knowledge, would command the confidence of local authorities and manufacturers.”

“In our opinion a properly equipped central authority is essential, and we unhesitatingly recommend the creation of such an authority.”

“In the interests of river purification as well as of the trade of the country we consider it is of the highest importance that the changes in the law which we have recommended should be made. But these changes would not in our opinion be of much use apart from the creation of a Central Authority for the determination of differences between the local authority and the manufacturer.”

“If the settlement of these differences be left to the ordinary Courts, differential treatment of manufacturers, with all the objections to it, will be certain to continue.

We also recommended that, for the due protection of rivers, Rivers Boards should be formed for other parts of the country, similar to the three which already exist in Lancashire and Yorkshire, and that these boards should be empowered to determine, subject to appeal to the Central Authority, certain of the differences between local authorities and manufacturers.

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* *See*, however, paragraph 10 of the Ninth Report in which we stated: “Our own additional experience and the further evidence which has been laid before us indicate that it may be desirable that local authorities should have a general power to make a charge, provided that the charges were lower in the case of effluents which had been subjected to preliminary treatment in accordance with the regulations.”

We further advised that it should be the duty of Rivers Boards to inspect public water supplies, and to report to the Central Authority any cases of dangerous pollution of such supplies which they may detect; and that the Central Authority should be empowered, after due inquiry, to order the purveyors of the water to adopt such means as, in the opinion of the Central Authority, were reasonable and necessary for removing or diminishing the danger.

We also recommended that the Central Authority might, with the aid of the Rivers Boards, very properly collect such information as is available throughout the country in regard to waste of water by pumping from mines, and in regard to the abstraction of water from one district for the supply of another district, to the detriment of the water supply of the district from which the water was taken. We considered that the collection of such information should precede the consideration of the question whether legislative interference in regard to these matters is desirable.

We may now add (1914) that it appears to us desirable that a Rivers Board should have a *locus standi* to appear before Parliamentary Committees in regard to any schemes affecting waters in their district.

FOURTH REPORT. CD. 1883 [1904].

In our Fourth Report, we dealt with the pollution of tidal waters, with special reference to the contamination of shell-fish. We stated that:

> " After carefully considering the whole of the evidence on this point, we are satisfied that a considerable " number of cases of enteric fever and other illnesses are caused by the consumption of shell-fish which have " been exposed to sewage contamination; but in the present state of knowledge, we do not think it possible " to make an accurate numerical statement, at any rate as regards the whole country."
>
> " There can, however, be no doubt that the evil is sufficiently grave to demand a remedy."

Our main recommendation for dealing with the evil was stated in the following terms:

> " After carefully considering the whole of the evidence, together with the results of our own investiga- " tions and local inquiries, we are strongly of opinion that the only way in which this evil can be effectively " dealt with is by placing tidal waters under the jurisdiction of a competent authority, and conferring on " that authority power to prevent the taking of shell-fish for human consumption from any position in which " they are liable to risk of dangerous contamination, and to enforce restrictions as regards pollution, and " as regards waters, foreshores, pits, ponds, beds and layings in which shell-fish are fattened or stored, as " and when required."
>
> " For this purpose the powers of the authority must be elastic. The case of each river and estuary is " a problem by itself, and it would not be practicable to fix by enactment any standard or standards which " would be generally suitable to the widely different conditions of different cases. Moreover, as the con- " ditions are shifting in character, it is necessary to provide some permanent machinery by which restrictions " can be varied."

After considering various alternative suggestions as to the Controlling Authority, we stated that:

> " We entirely agree with the view which has been pressed upon us by a large number of witnesses that " Rivers Boards would be the most suitable bodies in whom to vest the local control which we are now " discussing. Their control over inland waters is of a similar character to the control which is required " over tidal waters (estuarial and other), and it is desirable and fitting that their jurisdiction should be " extended to tidal waters for public health purposes. There are indeed no other local bodies possessing " the necessary qualifications, and the only practicable alternative to giving them jurisdiction would seem " to be to place the whole control in the hands of a Central Department."

We recommended therefore:

> " That the necessary power of control over the pollution of tidal waters, and over waters, foreshores, " pits, ponds, beds, and layings where shell-fish are grown, fattened or stored, should be vested in the Rivers " Boards, subject to appeal to a central authority."

In the Report we set forth, in detail, the procedure which the Rivers Boards and Central Authority should follow. We also dealt with the question of the means which should be adopted for avoiding danger from the consumption of foreign shell-fish.

As regards other evils, besides the contamination of shell-fish, which had to be guarded against in the case of discharge of sewage into tidal waters, we made recommendations dealing with these matters.

FIFTH REPORT. CD. 4278 [1908].

Our Fifth Report dealt chiefly with the relative merits of the various methods available for the purification of sewage of towns.

GENERAL CONCLUSION.

Our conclusions are summarised as follows:

> " It is practicable to purify the sewage of towns to any degree required, either by land treatment or " by artificial filters, and there is no essential difference between the two processes."

"The main questions, therefore, to be considered in the case of a town proposing to adopt a system of "sewage purification are, first, what degree of purification is required in the circumstances of that town, and "of the river or stream into which its liquid refuse is to be discharged; and, secondly, how the degree of "purification required can, in the particular case, be most economically obtained."

Removal of Suspended Matters.

"We find that it is generally desirable to remove from the sewage, by a preliminary process, a considerable "proportion of the grit and suspended matters, before attempting to purify the sewage on land or filters."

Sedimentation Tanks.

"*Quiescent Sedimentation.*—Two to three hours quiescence is usually sufficient to produce a tank liquor "fairly free from suspended solids, but owing to the fact that some sewages contain a larger proportion than "others of solids that settle very slowly, no general rule can be laid down as to the necessary period of quiescence. With this form of treatment the deposit in the tanks should be frequently removed."

"*Continuous Flow Sedimentation.*—The amount of settlement effected does not depend alone upon the "period of flow, but upon a number of other factors. If the tank liquor is to be treated upon filters of fine "material, the period of flow should generally be from 10 to 15 hours. The tanks should be cleaned out at "least once a week."

Septic Tanks.

"All the organic solids present in sewage are not digested by septic tanks, the actual amount of digestion "varying with the character of the sewage, the size of the tanks relative to the volume treated, and the "frequency of cleansing. With a domestic sewage, and tanks worked at a 24-hours rate, the digestion is "about 25 per cent.

"The liquor issuing from septic tanks is bacteriologically almost as impure as the sewage entering the "tanks."

"Domestic sewage which has been passed through a septic tank is not more easily oxidised in its passage "through filters than domestic sewage which has been subjected to chemical precipitation or simple sedimentation."

"No definite rules can be laid down as to how long a septic tank should be run without cleaning. In "the case of small sewage works (serving populations of say 100 to 10,000 persons), the tanks should generally "be allowed to run, without cleaning, so long as the suspended matter in the tank liquor shows no signs of "affecting the filters injuriously. For larger works it would generally be advisable to run off small quantities "of sludge at short intervals of time."

"The rate of flow through a septic tank is a matter in which the needs of each place require special consideration, but at few places should the sewage be allowed to take longer than 24 or less than 12 hours to "flow through the tank. In no case should less than two tanks be provided, and they should be arranged so "that, if necessary, one tank can be used alone."

"As regards digestion of sludge and quality of tank liquor, a closed tank possesses no advantages over "an open tank. There is less risk of nuisance if the tank and the feed channels to the filters are covered in."

"By passing septic tank liquor through tanks of a size sufficient to hold about one quarter of the day's "flow, with the addition of from 2 to 3 grains of lime per gallon to the liquor, the suspended solids in the "liquor are materially reduced, a considerably larger quantity of the liquor can be treated per cube yard of "filter, and the offensive character of the liquor is largely destroyed."

Chemical Precipitation.

"In the case of sewages which contain certain trade waste, and strong sewages from water-closet towns "it is generally desirable to subject the sewage to some form of chemical treatment before attempting to "oxidise the organic matter contained in it. In most cases careful chemical precipitation materially aids the "deposition of the suspended solids, and facilitates subsequent filtration."

"No general rule can be stated with regard to the capacity of precipitation tanks. With continuous flow, "an eight-hours rate is usually sufficient to produce a fairly good tank liquor from a domestic sewage of average "strength."

"If sewage is allowed to remain quiescent in the tank, two hours settlement would usually suffice."

Relative Cost of Different Tank Treatments.

"In the absence of special circumstances favouring a particular plan, it would appear that there is very "little difference in annual cost between the various methods of tank treatment when taken in conjunction "with the cost of subsequent filtration through percolating filters, assuming that the kind of filter adopted in "each case is that which is best adapted to the particular tank treatment provided."

Filters.

"Within ordinary limits, the depth of a contact bed makes, practically, no difference to its efficiency per "cube yard."

"We think that it would be generally inadvisable to construct contact beds of a greater depth than 6 feet "or of a less depth than 2 feet 6 inches."

"For practical purposes and assuming good distribution, the same purification will be obtained from a "given quantity of *coarse* material, whether it is arranged in the form of a deep or of a shallow percolating "filter, if the volume of sewage liquor treated per cube yard be the same in each case."

"With regard to percolating filters of *fine* material, if the liquid to be purified were absolutely free from "suspended and colloidal solids, and if thorough aeration could be maintained, the statement just made for "filters of coarse material might possibly hold good for filters of fine material also. In practice, however,

" these conditions can scarcely be maintained with large rates of flow, and we think that the greatest efficiency " can be got out of a given quantity of *fine* material by arranging it in the form of a shallow filter " rather than of a deep filter. But we are not in a position to make an exact quantitative statement as to " the difference in efficiency of the two forms."

" The amount of sewage which can be purified per cube yard of contact bed or of percolating filter varies— " within practical limits—nearly inversely as the strength of the liquor treated. This statement is based on " the assumption that the size of the material of which the filter is composed is, in each case, suitable to the " character of the liquor treated, and that the material is arranged at the proper depth to secure maximum " efficiency."

" Taking into account the gradual loss of capacity of contact beds, a cubic yard of material arranged in " the form of a percolating filter will generally treat about twice as much tank liquor as a cubic yard of material " in a contact bed."

" In the case of sewage containing substances which have an inhibitory effect upon the activity of micro- " organisms, the working power per cube yard of filter of either type may be more nearly equal. This point, " however, is not clearly established."

" Percolating filters are better adapted to variations of flow than contact beds."

" Effluents from percolating filters are usually much better aerated than effluents from contact beds, " and, apart from suspended solids, are of a more uniform character. On emptying a contact bed, the first " flush is usually much more impure than the average effluent from the bed."

" The risk of nuisance from smell is greater with percolating filters than with contact beds."

" With percolating filters there is apt to be a nuisance from flies, especially with filters constructed of " coarse filtering material. In the warmer months of the year, such filters swarm with members of the " *Psychodidæ*, which, though appearing to breed and develop in the filters, may usually be seen in large numbers " on the walls of houses, or buildings close to or on the works."

Treatment of Sewage on Land.

" There is no essential distinction between effluents from land and effluents from artificially constructed " filters."

" Effluents from those soils which are particularly well adapted for the purification of sewage contain " only a very small quantity of unoxidised organic matter, and are usually of a higher class than effluents " from artificial filters as at present constructed and used."

" Effluents from soils which are not well adapted for the purification of sewage may often be very impure,"

Sludging of Mill Dams.

" In any case in which the Rivers Board should be of opinion that the sludging of a mill dam by turning " the accumulated sludge into the stream would give rise to a nuisance and that it would be financially practic- " able for the mill owner to adopt some other method of cleansing the dam, the Rivers Board should be em- " powered, by notice, to direct the mill owner not to turn the sludge into the stream."

" It should be provided that any mill owner deeming himself aggrieved by such a direction, might, within " some fixed period, appeal to the Central Authority. The decision of the Central Authority should be final."

" Should any cases arise, in which it is important that the sludge should not be turned into the stream, " but in which the Rivers Board are of opinion that the cost of adopting any other method of cleansing the " dam would be prohibitive to the mill owner, we recommend that the Rivers Board should be empowered " to represent the case to the Central Authority, and that the Central Authority should be empowered, after " due inquiry, to direct that the sludge shall not be turned into the stream. If the Central Authority should " be satisfied that the cost of adopting some other method of cleansing the dam would be greater than the " mill owner could be reasonably called upon to bear, they should be empowered to direct that a portion of " the cost should be borne by the local authorities whose districts would be benefited."

Effect of Trade Effluents on Sewage Purification.

" All the trade effluents of which we have had experience interfere with or retard processes of purification " to some extent, but we are not aware of any case where the admixture of trade refuse makes it impracticable " to purify the sewage upon land or by means of artificial processes, although in certain extreme cases special " processes of preliminary treatment may be necessary."

Nuisance from Smell.

" All sewage works are liable, at times, to give off unpleasant smells ; they should, therefore, be situated " away from dwelling-houses, wherever this is practicable."

" The nuisance is apt to be considerably greater where the sewage contains brewery refuse in any quantity ; " but, on the other hand, the presence of some trade effluents such, *e.g.*, as iron salts or tarry matters, tends " to render the process of purification less offensive."

" The extent of the risk of nuisance depends, however, not only on the character of the sewage, but also " on the method of treatment adopted."

General Observations bearing on Choice of a Method of Sewage Treatment.

" The selection of a method of sewage disposal should depend primarily on local conditions."

" If a sufficient quantity of good land, to which the sewage can gravitate, can be purchased for about " £100 an acre, land treatment would usually be the cheapest method to adopt."

" In cases where only clay land is available, it would generally be cheaper and more satisfactory to provide " artificial filters."

" Given conditions favourable to each process, there is little difference as regards cost between any of " the different forms of tank treatment when these are considered along with the cost of subsequent filtration."

"Single contact will, generally, only yield a good effluent where the sewage to be treated is weak, and then only after good preliminary treatment. For the purification of partially settled weak sewage, and for well, as also for partially, settled sewage of average strength, if the case is one in which a good effluent is required, double contact is necessary, while if a strong sewage has to be treated, triple contact is necessary, unless the preliminary treatment is exceptionally good."

"In nearly every case a greater rate of filtration per cube yard can be adopted if the material is arranged in the form of a percolating filter, than if it is used in contact beds. In many cases the rate of filtration through percolating filters may be double or nearly double what it could be with contact beds."

"Where the liquor to be treated contains much suspended matter, it is usually advisable to construct filters, whether contact or percolating, with coarse filtering material. Where the preliminary treatment has effectively removed the greater part of the suspended matter, it is best to use fine material in the filters."

Storm Overflows on Branch Sewers.

"Storm overflows on branch sewers should be used sparingly, and should usually be set so as not to come into operation until the flow in the branch sewer is several times the maximum normal dry weather flow in the sewer. No general rule can be laid down as to the increase in flow which should occur in the branch sewers before sewage is allowed to pass away by the overflow untreated. The Rivers Board, or in districts where there is no Rivers Board, the County Council, should have power to require the local authority to alter any storm overflows which, in their opinion, permit of an excessive amount of unpurified sewage to flow over them. The local authority should have the right to appeal to the Central Authority in any case in which they consider that the requirement of the Rivers Board is unreasonable or impracticable of fulfilment."

"The general principle should be to prevent such an amount of unpurified sewage from passing over the overflow as would cause nuisance."

Treatment of Storm Water Sewage at the Works.

"As a general rule, special stand-by tanks (two or more) should be provided at the works, and kept empty for the purpose of receiving the excess of storm water which cannot be properly passed through the ordinary tanks. As regards the amount which may be properly passed through the ordinary tanks, our experience shows that in storm times the rate of flow through these tanks may usually be increased to about three times the normal dry weather rate without serious disadvantage."

"The overflow at the works should be made from these special tanks, and should be arranged so that it will not come into operation until the tanks are full."

"Special filters which are only used in times of storm are not usually efficient, and should not be provided."

"Any extra quantity of sewage arriving at the works in storms, which has to be filtered, should be treated on the ordinary filters, which should be made sufficiently large for the purpose".

"As regards the size of the stand-by tanks, the amount of storm water sewage to be filtered, and the arrangements generally for dealing with the storm sewage at the outfall works, the Rivers Board or the County Council in areas in which no Rivers Boards have been established should have similar power to that which we have proposed in regard to overflows on branch sewers, and the local authority should have a similar right of appeal to the Central Authority."

"In most cases it will probably suffice to provide stand-by tanks capable of holding one quarter of the daily dry weather flow, and it will not be necessary to provide for *filtering* more than three times the normal dry weather flow."

"Under the arrangements which we recommend no storm sewage arriving at the outfall works would be discharged without some settlement."

Separate Systems of Sewers.

"In any case in which a local authority wishes to adopt the separate system of drainage for the whole or any part of their district, they should apply to the Central Authority, and that Authority should be empowered to confer on the local authority, by order, such powers as are required."

"As regards the powers that are required, the provisions which are generally contained in local Acts in respect of this matter seem to be defective. If separate sewers are provided, the local authority should have a clear power to enforce the provision of separate drains, but the local Acts to which our attention has been drawn do not modify the powers of the local authority under the general law in regard to bye-laws as to the drainage of houses. Moreover, the powers of the local authority should not necessarily be limited to new streets and new houses."

"As a general rule, the expense of altering existing drains should fall on the local authority, and there may be some instances in which it would be equitable that they should bear some portion of the additional cost even in the case of new roads."

"The Central Authority should, therefore, have power to include in their Order such provisions for the allocation of the cost as they consider equitable, having regard to the local circumstances."

Standards for Sewage Effluents.

"Our terms of reference require us to have regard to the '*economical* and efficient' discharge of the duties of local authorities, and in view of the importance of not requiring a local authority to incur any further expenditure on sewage disposal than the circumstances of its area require, we feel strongly that the law should be altered so as to allow local circumstances to be taken into account."

"We recommend that the Central Authority should determine the nature of the tests which are to be applied for the purpose of standards, and that it should be made the duty of the Rivers Board, or of the County Council in areas not under the jurisdiction of a Rivers Board, to determine, from time to time, subject to appeal to the Central Authority, what standards should be adopted."

" In the first instance it would be convenient that the Central Authority should prescribe one standard " for all non-tidal waters, in place of the existing statutory provisions. It would then rest with the Rivers " Board or County Council to fix, subject to appeal to the Central Authority, a higher or lower standard in " any case in which they were of opinion that the circumstances required or justified a different standard."

" We further recommend that no action should be allowed to be brought in respect of damage alleged " to be due to the discharge of an effluent which complies with the standard fixed for the water into which " it is discharged, but that in such cases complaint should be made to the Central Authority, and, if a *prima* " *facie* case is made out, that Authority should ascertain whether the complaint is well founded, and should " be empowered to fix a different standard if the circumstances are shown to require it."

" In cases where it is alleged that the effluent does not comply with the statutory standard, and that " damage is caused by the discharge of such effluent, action should be brought in the ordinary Courts."

" But any questions arising as to whether the effluent complies with the statutory standard, or as to " whether the damage has been caused by the discharge of the effluent in respect of which complaint is made, " should be referred by the Court to the Central Authority for determination. The costs of such determina- " tion should be borne by the parties to the action in such proportions as the Court may determine."

" Power should be conferred on the Central Authority to suspend, from time to time, the operation of " any standard, to allow time for the construction of works, or for any other reason which, in their opinion, " justified such suspension."

*Tests for Sewage Effluents in Relation to Standards.**

" According to our present knowledge, an effluent can best be judged by ascertaining, first, the amount " of suspended solids which it contains, and, second, the rate at which the effluent, after the removal of the " suspended solids, takes up oxygen from water."

" In applying this test it is important that the suspended solids should be removed, and estimated " separately."

" For the guidance of local authorities we may provisionally state that an effluent would generally be " satisfactory if it complied with the following conditions :—

(1) That it should not contain more than 3 parts per 100,000 of suspended matter ; and

(2) That, after being filtered through filter paper, it should not absorb more than :

(*a*) 0·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 24 hours.

(*b*) 1·0 part by weight per 100,000 of dissolved or atmospheric oxygen in 48 hours ; or

(*c*) 1·5 parts by weight per 100,000 of dissolved or atmospheric oxygen in 5 days.

THE CENTRAL AUTHORITY.

" To secure the economical and efficient discharge of the duties of local authorities, and others, in regard " to pollution, and adequately to protect the public health and the amenities of rivers, the statutory provisions " in regard to these matters must be of an elastic character."

" The conditions of different cases vary to such an extent that the necessary control cannot, in our " opinion, be provided by any direct enactment which could be enforced by the ordinary Courts."

" Throughout our Reports, this fact has been fully recognised, and we have proposed, in regard to many " matters, that ultimate control should be vested in an adequately equipped Central Administrative Authority, " and that, as far as practicable, the local Rivers Board should, in accordance with regulations framed by the " Central Department, act as a first tribunal."

" Among the more important questions which have to be dealt with under the new conditions of ad- " ministration which we are contemplating, are the following :—

(i.) Disputes between local authorities and manufacturers as to the terms and conditions on which trade effluents shall be admitted into sewers.

(ii.) The control of shell-fish layings so as to prevent the taking of shell-fish for human consumption from positions in which they are liable to risk of dangerous contamination.

(iii.) The protection of water supplies from pollution.

(iv.) The collection of information as to the water supplies available in various parts of the country.

(v.) The collection of information as to the need of water in various parts of the country.

(vi.) The settlement of standards for different reaches of water.

(vii.) Conferring powers on local authorities, in suitable cases, to provide separate systems of sewers for surface water and to enforce the provision of separate drains.

(viii.) The settlement of questions as to the extra amount of sewage which a local authority should be required to treat during storms.

" There are also numerous questions in regard to the purification of polluting liquids which, in the interests " of the public, have still to be worked out, and it is essential that the Central Authority should be property " equipped for undertaking such special investigations as they may from time to time find necessary, and " for collecting and collating the work done by others."

" Since the date of our appointment considerable developments have taken place in regard to the disposal " of sewage, and there is every reason to think that further changes will occur in the future."

" Unless the Central Department keep in close touch with all such changes, and from time to time report " on them, it is not possible for local authorities throughout the country fully to utilise the results of valuable " work which is being done at many places, and hence, to perform their duties in the most economical as " well as efficient manner."

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* Our final recommendations on the subject of Standards are contained in our Eighth Report.

SIXTH REPORT. CD. 4511 [1909].

In our Sixth Report we considered the question of the purification of distillery waste. We investigated the methods which were generally in use for purifying the most polluting waste liquor, which is known as "burnt ale" or "pot ale," as well as the other waste liquors. These methods were land treatment—destruction by heat—evaporation, followed by torrefaction—and purification by means of contact beds.

We also carried out experiments on a practical scale with percolating filters erected at the Coleburn Distillery.

The conclusions at which we arrived were stated as follows:

"1. It is practicable to treat the waste liquids from distilleries either on land or on filters so as to produce "a satisfactory effluent."

"2. For treatment of these liquids, percolating filters are more efficient than contact beds, and, according "to present knowledge, it appears to be desirable first to dilute the waste liquids and then to treat them "with lime before filtering them."

"3. It is practicable to destroy *pot ale* by heat. For this purpose the waste heat of the works may be "utilised, but this alone is only sufficient to destroy about one-third of the pot ale produced.

"4. It is practicable to evaporate *pot ale* and then to incinerate the syrup so as to produce a manure "which at present sells fairly well at about £5 a ton."

"The revenue from the sale of such manure falls far short of the expenditure required to produce it."

"There is some risk of atmospheric nuisance with these destructor and evaporation processes, as at present "carried on, and the distillate from the evaporation process is a liquid which would be liable to cause a nuisance "if discharged into a small stream."

"5. The cost of the various methods of dealing with the waste liquids from distilleries would depend "largely on local circumstances. Where suitable land was available at an agricultural price, land treatment "would be the most economical process to adopt, but great care would be required to secure that the land is "not overdosed and that the waste liquids are properly distributed over it."

"Of the artificial processes, the plan which has been carried out at Coleburn, would, in our opinion, "be considerably cheaper than any of the destructor or evaporation processes, especially in view of the fact "that these processes only deal with *pot ale*. So that where they are adopted further means must be pro- "vided for purifying the other waste liquids."

"In making this statement we are assuming that skilled supervision would be required in all cases, but "especially in the case of the process which has been carried out at Coleburn."

"6. The Central Authority, which we have recommended to be constituted should be the final tribunal "to determine all questions relating to standards."

"7. In the case of distilleries situated in towns which are sewered, we think, as a general rule, the liquid "refuse should be allowed to enter the sewers. Its admission to the sewers should be subject to regulations "and safeguards, as recommended in our Third Report, dealing with the relations between local authorities "and manufacturers in regard to the disposal of manufacturing effluents."

Further, in response to the request of the distillers that we would consider the question of fixing some standard of purity up to which it would be safe for the riparian proprietors to receive effluents from distilleries into the stream, we stated:

"As regards the effluent which the riparian proprietors require, any claim that the effluent shall in com- "position be identical with the river water, without reference to the question of damage, is not, in our opinion, "one which should be entertained."

"There are undoubtedly a large number of instances in which it would be physically impossible for any "such demand to be satisfied; and, if it were to be insisted on, it would involve the stoppage of many of "the distilleries of the country."

"The extent to which distillery effluents need be purified, in order that no damage should be caused to "the stream into which they are discharged, would vary with the particular circumstances."

"In the case of small fishing rivers, such as the Dullan and Fiddich, where a high standard of effluent "is necessary, we consider that an effluent would probably prove satisfactory if it complied with the following "conditions:—

(1) That it should not contain more than three parts per 100,000 of suspended matter;

(2) That it should be non-putrescible on incubation; and

(3) That, after being filtered through filter paper, it should not absorb more than 1·5 parts *by weight* per 100,000 of dissolved or atmospheric oxygen in five days.

"This is quite a practicable standard of purification. The effluent from the plant at Coleburn was "generally much better."

"In many other cases a lower standard would, in our opinion, suffice."

SEVENTH REPORT. CD. 5542 [1911].

Our Seventh Report dealt with nuisances due to green sea-weeds in sewage polluted estuaries, with special reference to Belfast Lough.

In this investigation we paid particular attention to Belfast Lough, but we also extended our observations to Southampton Water, Poole Harbour, and several other places where green sea-weed (particularly *ulva latissima*) were found.

Our investigations comprised chemical and bacteriological examination of waters and muds from these localities, chemical analyses of the weeds, and a close study of their habits and growth under different conditions, both natural and artificial.

Our observations and experiments pointed to the conclusion that while *ulva* can grow freely without any sewage pollution, the addition of nitrogen in a form which may be supplied by sewage is apt to produce rapid increase of the weed. We found that physical conditions other than a particular quality of the water are essential to the growth of the weed in any quantity, the chief of these conditions being sheltered and shallow waters with sluggish currents, and the existence of means of anchorage for the weed.

We also expressed our opinion, based on a comparison of the sulphur contents of *ulva* growing in polluted and unpolluted waters, that, " given similar conditions of decay, it would seem so far as the sulphuretted hydrogen is due to the sulphur in the weed, that, bulk for bulk, *ulva* from unpolluted sources may be capable of causing at least as serious nuisance as *ulva* from Belfast Lough."

Removal of sewage pollution, therefore, could not be a complete and certain remedy for nuisance caused by decaying masses of the weed.

To meet the particular case of Belfast we recommended a variety of special remedial measures.

EIGHTH REPORT. CD. 6464 [1912].

Our Eighth Report dealt in greater detail with the question of the standards to be applied to sewage and sewage effluents discharging into streams, and of the tests to be used in determining those standards, on which we had made provisional recommendations in our Fifth Report.

Our object was to devise a system whereby a local authority should not be required to incur any further expenditure on sewage disposal than would suffice to prevent the occurrence of actual nuisance.

We found, as a result of prolonged observations on a number of streams, that the most reliable chemical index of the nuisance-producing power of a polluted stream is the amount of dissolved oxygen taken up in 5 days, and, further, that if the stream water normally takes up more than 0·4 part per 100,000 dissolved oxygen in 5 days, nuisance is likely to be caused. If, then, at no point of its course the water of a stream took up more than 0·4 part per 100,000 dissolved oxygen in 5 days, no objectionable conditions were likely to be present. Given the volume and quality of the river water and the volume of the effluent, it would be easy to calculate what should be the quality of the effluent (as judged by the dissolved oxygen absorption test) which would ensure that the mixture of effluent and river water should not take up more than 0·4 part dissolved oxygen.

But, while such a calculation should be the basis of any system of standards, it would not be practicable to employ as a working standard a figure which was the resultant of several variable factors; such a procedure would permit the discharge of an effluent varying in quality, not only from place to place, but even from day to day in the same place. For administrative reasons we considered that there should be a fixed general standard applied to the effluent alone, and that this standard should be relaxed or made more stringent as local circumstances permitted or required.

In order to arrive at a standard of general application to effluents which should, at the same time, be based on the above figure of 0·4 for river waters, it was necessary to make certain assumptions, and to allow a margin of safety for cases in which the assumption was not in fact well founded.

In the first place, we considered that variations in the quality of the water into which an effluent was discharged should not be taken into account for the purpose of arriving at a standard. Local authorities are not responsible for the quality of the river water above their outfall works, and they should not be required to purify their effluent to an exceptional degree because the water with which it was to be diluted was exceptionally impure. In such a case the remedy should be applied to pollutions higher up the stream.

On the other hand, local authorities are, to a greater or less degree, responsible for the quality of the river water below their outfall, and it is undesirable that they should be entitled to impair to the verge of nuisance a stream water of more than average purity by discharging into it an effluent of less than average purity.

Hence we thought the proper course would be to assume that the river water was neither exceptionally polluted nor exceptionally pure. Analyses of a number of streams, which on the strength of their observed condition were classified as being of average purity, yielded an average figure of 0·2 part per 100,000 dissolved oxygen taken up in 5 days. We considered that for purposes of calculation the quality of diluting water should be assumed to be constant, and represented by the figure 0·2.

The governing factor in selecting one of several possible standards should, we considered, be the volume of river water as compared with the effluent. In our Fifth Report we stated provisionally that an effluent would generally be satisfactory if it did not contain more than 3 parts per 100,000 of suspended matter, and if, after being filtered through filter paper, it did not absorb more than 1·5 parts per 100,000 dissolved oxygen in 5 days. Further experience showed that filtration through filter paper introduced an element of uncertainty, and that the effluent should preferably be judged with its suspended solids included. In that case we showed that a figure of 2·0 parts dissolved oxygen absorption per 100,000 was comparable with the figure of 1·5 previously suggested, and was also attainable in practice.

An effluent taking up 2·0 parts dissolved oxygen per 100,000 would be found by a simple calculation to require dilution with at least 8 volumes of river water taking up 0·2 part if the resulting mixture was not to take up more than 0·4 part. Our experience indicated that in a large majority of cases the volume of river water would exceed 8 times the volume of effluent, and that the figure of 2·0 parts dissolved oxygen per 100,000, which had been shown to be practicable, would be a safe figure to adopt for the purposes of a general standard, taken in conjunction with the condition that the effluent should not contain more than 3·0 parts per 100,000 of suspended solids.

In special cases where the dilution was less than 8 times the volume of effluent provision should be made for prescribing more stringent standards.

On the other hand, where the dilution was very much greater than 8 volumes a less stringent standard than the general standard would suffice to prevent nuisance.

In order to comply with the general standard a complete system of purification—including biological treatment in artificial filters or on land—would be required. We gave a series of calculations to show that given a certain degree of dilution biological treatment could safely be dispensed with, and chemical precipitation would suffice; given greater dilution simple settlement would be enough, and with still greater dilution even this mode of treatment might be omitted.

We summed up our conclusions as follows:

"(*a*) The law should be altered so that a person discharging sewage matter into a stream shall not be "deemed to have committed an offence under the Rivers Pollution Prevention Act, 1876, if the sewage matter "is discharged in a form which satisfies the requirements of the prescribed standard."

"(*b*) The standard should be either the general standard or a special standard which will be higher or "lower than the general standard as local circumstances require or permit."

"(*c*) An effluent in order to comply with the general standard must not contain as discharged more than "3 parts per 100,000 of suspended matter, and with its suspended matters included must not take up at "65° F. (18·3° C.) more than 2·0 parts per 100,000 of dissolved oxygen in 5 days. This general standard "should be prescribed either by Statute or by order of the Central Authority, and should be subject to modifi"cations by that Authority after an interval of not less than ten years."

"(*d*) In fixing any special standard the dilution afforded by the stream is the chief factor to be con"sidered. If the dilution is very low it may be necessary for the Central Authority, either on their own "initiative or on application by the Rivers Board, to prescribe a specially stringent standard, which should "also remain in force for a period of not less than ten years."

"(*e*) If the dilution is very great the standard may, with the approval of the Central Authority, be relaxed "or suspended altogether. Our experience leads us to think that as a general rule, if the dilution, while not "falling below 150 volumes, does not exceed 300, the dissolved oxygen absorption test may be omitted, and "the standard for suspended solids fixed at 6 parts per 100,000. To comply with this test no treatment "beyond chemical precipitation would ordinarily be needed. If the dilution while not falling below 300 "volumes does not exceed 500 the standard for suspended solids may be further relaxed to 15 parts per 100,000. "For this purpose tank treatment without chemicals would generally suffice if the tanks were properly worked "and regularly cleansed. These relaxed standards should be subject to revision at periods to be fixed by "the Central Authority, and the periods should be shorter than those prescribed for the general or for the "more stringent standards."

"(*f*) With a dilution of over 500 volumes all tests might be dispensed with, and crude sewage discharged "subject to such conditions as to the provision of screens or detritus tanks as might appear necessary to the "Central Authority."

We also made recommendations on the following points :—

Regulations of the Central Authority.

" The working of the machinery which we have suggested will be greatly simplified if the Central Authority " draw up a code of instructions or regulations for the guidance of Rivers Boards and local authorities. This " code should indicate the circumstances in which special standards would be permitted and should define, " as far as practicable, the nature of those standards."

The Taking and Analysis of Samples.

" We think it is desirable that local authorities discharging liquid refuse into streams should take periodical " samples representative of the character of their effluent or sewage liquor, and should submit these samples " to the tests required by the standard and to any other tests which may be prescribed by regulations of the " Central Authority ; and that they should keep systematic records of the analytical results."

" Facilities should also be provided for the inspection of these records by the Rivers Boards or Central " Authority, and for the taking and testing of samples by those authorities. Sampling chambers should be " provided in every case as near the outfall as questions of fall and other local conditions permit. These " matters would be proper subjects for regulations by the Central Authority, which should also make pro- " vision in regard to the enforcement of standards, if necessary, by legal proceedings. We do not anticipate " that a Rivers Board would ordinarily take proceedings on the strength of a single sample which failed to " satisfy the standard ; but we think it essential that they should be empowered to do so, in order to prevent " occasional but wilful discharge of highly polluting matter by the improper use of bye-pass valves or over- " flows or by other surreptitious means."

Gauging.

" The volume of sewage liquor or effluent discharging into a stream is, as we have explained, a factor of " the greatest importance in fixing the appropriate standard, and the regulations should provide for the tanks " or other works being so constructed as to facilitate accurate gauging and drawing of average samples.

Power of Entry.

" We think that the officers of the Central Authority and of the Rivers Boards should have statutory " authority to enter upon lands at any time without notice for the purpose of inspecting works and rivers " and taking samples of the liquor or effluent and river water wherever they can be obtained. The Rivers " Pollution Prevention Act, 1876, contains no provision on this subject, but reference may be made to sections " 16 and 17 of the Alkali Works Regulation Act, 1881, section 98 of the Thames Conservancy Act, 1899, and " section 7 of the Middlesex County Council Act, 1906. In the Mersey and Irwell Joint Committee Act, " 1892 (section 10) and the West Riding of Yorkshire Rivers Act, 1894, the power to take samples is limited " to the point at which the effluent enters the stream. We think this limitation is undesirable."

Storm Water Sewage.

" We consider that the standards should not apply to storm water sewage. In regard to this matter we refer " to paragraphs 292 to 295 of our Fifth Report,* and we repeat our recommendations with regard to storm " overflows and the treatment of storm sewage, the adoption of which would in our opinion prevent the " occurrence of nuisance."

Tidal Waters.

" In part VII. of our Fifth Report we summarized the position in regard to the pollution of estuaries and " tidal waters (which we dealt with at length in our Fourth Report) and stated that we did not think it practicable to lay down fixed rules as regards a standard of effluent for tidal waters."

" We do not now suggest that the general standard should apply automatically to tidal waters as in the " case of non-tidal waters, but we think that the principle which we have recommended in regard to special " standards for streams might usefully be applied to tidal waters where a standard is considered necessary."

NINTH REPORT. (CD. 7819.)

Our Ninth Report dealt (i.) with the discharge of manufacturing wastes which for any reason could not be taken into sewers, and (ii.) with the disposal of domestic refuse in rural areas. In the first part we gave a detailed account of most of the chief trade processes by which waste liquids were produced, of the character of those liquids, and of the means which had been or could be adopted for purifying them. This account embodied the results of our own observations at a number of works which were selected on the advice of Rivers and County Authorities as being fairly representative of the various trade processes and as including the best examples of purification plant ; it also contained the results of experiments which we had instituted in regard to certain trade liquids, the purification of which was especially difficult. We also utilised information placed at our disposal both by manufacturers and by officials of the West Riding of Yorkshire Rivers Board and the Mersey and Irwell, and Ribble Joint Committees.

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* These paragraphs are summarised on page 7 above.

We found that efficient means of purification were available in the case of some, but not all trade liquids. Many wastes, the impurities of which were mainly in solution, could be considerably improved by clarification, but could not, in the present state of knowledge, be thoroughly purified.

Hence the requirement of the existing law that trade wastes should (subject to certain exceptions) be rendered " harmless " was in many cases impracticable, and the authorities charged with the duty of administering the law had to exercise their own discretion in regard to the degree of purification to be demanded of manufacturers. We considered therefore that, as in the case of sewage effluents, there should be prescribed for trade effluents a standard of purity which should at once be a guide to the administrative authorities and a security to the manufacturers in regard to the extent of their obligations.

We found, further, that owing to the wide differences in the character of the various trade wastes, both as regards their effect upon steam and as regards the difficulty and expense of treating them, it would be necessary to consider each kind of trade waste separately with a view to suggesting an appropriate standard. We gave reasons for thinking that it was not desirable or necessary to prescribe a graduated system of standards (as we proposed in the case of sewage effluents), but that a single standard for each trade would suffice, provision being made for raising or lowering the standard where shown to be necessary in exceptional cases.

For the purpose of suggesting standards for the different trade wastes, we found it convenient to classify the wastes as follows :—

" (A) Those for which efficient purification is practicable ;

" (B) Those for which efficient purification is not in the present state of knowledge practicable."

" In Class A, we include waste liquors resulting from :

(i.) Coal washing.
Tin mining.
Lead and zinc mining.
China clay works.
Stone quarrying.
Stone polishing.
Wood pulp paper works.

In all these cases adequate reduction of solids in suspension may be regarded as efficient purification.

(ii.) Brewing.
Malting.
Distilling.
Tin plating.
Galvanizing.
Wire Drawing.
Shale oil distillation.
Woolscouring.
Tanning.
Leather dressing.
Fellmongering.
Dairying.

In these cases dissolved impurities should also be removed.

" In Class B, we include waste liquors resulting from :

(i.) Bleaching.
Waste bleaching.
Paper works (except where paper is made from wood pulp only).
Cotton dyeing.
Cotton printing.
Woollen dyeing.
Woollen piece and yarn scouring with dye liquor.

(ii.) Sulphite cellulose manufacture.
Gas and coke production.

" Although no practicable means are known for rendering completely harmless the liquids included in " this class, nearly all of them can be and are considerably improved by clarification.

" We have placed sulphite cellulose liquor and gas liquor in a separate sub-division because we are " not aware of any method of so treating them that the effluents could properly be discharged direct into " streams."

As regards the standards to be prescribed, we stated as follows :—

" We think it impossible to lay down, as regards each trade, such a standard as would ensure the com- " plete purification of rivers, since, in the present state of knowledge, the attainment of such a standard would " in many cases be financially impracticable and therefore useless. We have thought it useful, however, " to suggest limits of impurity which we believe to be now practicable, and which are based upon careful " consideration of the data given in the detailed sections."

"These figures will afford guidance to the Central Authority when established, and, although provisional "and based upon the present condition of knowledge, they should, in our opinion, if prescribed, remain in "force for a definite period. At the end of this period they would be subject to revision, since admittedly "they are inadequate to prevent pollution of streams, and improved methods of treatment may meanwhile have been discovered."

"In regard to the periods for which standards for sewage effluents should remain in force we made the "following suggestion in our Eighth Report :—

> '(52) We think it of importance that a standard once imposed upon a local authority should 'not be altered until the expiration of a definite period, in order that they may have some security 'as to the extent of their liability.'
>
> 'We suggest that these periods should be prescribed by Order of the Central Authority, and 'should in the case of the general or any specially stringent standard be not less than ten years 'from the date when the standards came into operation. In the case of relaxed standards the periods 'should be shorter. The less elaborate the plant required to meet a standard, the less hardship 'there will be in reducing the period during which the standard should remain in force ; and, on the 'other hand, it is desirable to offer the local authorities some inducement, in the shape of a more 'prolonged immunity from interference, to carry purification beyond the minimum. By the end 'of those periods the Central Authority should have acquired sufficient experience to enable them 'to decide whether the general standard required any modification (which we suggest they should 'be empowered to effect by the issue of an Order), and also to revise, where necessary, the special 'standards in particular cases.'

"We think the Central Authority might well consider whether a similar principle might not be applied "to standards for trade effluents, viz., that in the case of those trades where a standard involving expensive "plant is prescribed, the period might be longer than in those where only partials mean of purification are as "yet known. In the latter case the period could of course be extended if in the meantime no improved methods "of treatment had been discovered."

CLASS A.

"(i) In this sub-division, as we have pointed out above, reduction to a low figure of the solids in suspension may be regarded as efficient purification, and this can be effected by adequate settlement."

Coal Washing.

"We think that the effluent should not contain more than 4 parts of suspended solids per 100,000. In "a number of cases this standard might have to be relaxed."

Tin, Lead and Zinc Mines, China Clay Works, Stone Quarries, and Stone Polishing Works.

"Here we suggest provisionally a standard of 6 parts suspended solids per 100,000. So far as our evidence "shows, reduction of suspended solids to this extent should obviate danger to cattle or fish from poisoning "by lead, tin, antimony or arsenic."

"There are, however, cases in which no interests other than those of the particular industry are affected "by the discharge of the waste waters. If it can be shown, *e.g.*, in the case of small streams near to the sea, "which are not used for fishing, for navigation, for watering cattle, or for manufacturing purposes, that no "damage is caused by the discharge of waste waters without treatment, we think that the standard might "be relaxed or wholly dispensed with.

Paper Mills where wood pulp alone is used.

"In this case the effluent should not contain more than 4 parts suspended solids per 100,000."

Class A (ii).

"In this sub-division, reduction of dissolved as well as suspended impurities is necessary."

Breweries and Maltings.

"We suggest that the effluents should contain not more than 4 parts per 100,000 suspended solids and "should take up not more than 4 parts per 100,000 dissolved oxygen in five days."

Distilleries.

"For the various methods of treating this waste, we refer to our Sixth Report. Since the issue of that "Report we have kept under observation plants which were erected on the lines which we recommended, "and have found them both efficient and economically practicable. We recommend a standard of 3 parts "suspended solids and 2 parts dissolved oxygen absorption in 5 days. (This corresponds with the genera "standard which we have suggested for sewage effluents.)"

Tin Plating, Galvanising and Wire Drawing.

"These wastes are strongly acid from mineral acid and contain much iron in solution. The stronger "liquids should not in any circumstances be allowed to discharge into streams. The wash waters should "be neutralized and settled."

"We suggest that the standard for these wash waters should be 6 parts per 100,000 suspended solids."

"Even after compliance with this standard, a somewhat yellow and colloidal liquid might result. It "might possibly have to be softened before discharge, but we do not think it necessary at present to suggest "any standard of hardness."

Shale Oil Distillation.

"The standards which we suggest are 4 parts per 100,000 suspended solids and 4 parts per 100,000 dissolved oxygen absorption in 5 days (*see* p. 153)."

Woolscouring Liquor.

"Though the precipitation liquor, obtained by subjecting wool-scouring liquor to direct precipitation, " is practically free from fat, it remains very strongly organic and may be regarded as similar to a highly " concentrated sewage liquor; and the same may be said of the septic tank liquor from wool suds, which " also contains much sulphuretted hydrogen."

"For this reason we consider that the liquor should be looked upon as a sewage and purified biologically. " This treatment has so far only been carried out in the laboratory, but we are of opinion that it is practicable " at a reasonable cost, and, subject to our conclusion being verified by experiments on a large scale, we recommend a standard of 4 parts suspended solids and 4 parts dissolved oxygen absorption in 5 days."

"Pending such experiments we would suggest, for this type of precipitation liquor, clarification down " to 6 parts of suspended solids per 100,000."

Tannery Waste, Leather Dressers' Waste and Fellmongers' Waste.

"These wastes are also highly polluting and contain much organic matter of animal origin in solution. " Our observations in regard to the treatment of wool suds are equally applicable to these wastes, and we " make a similar suggestion in regard to a standard, viz., 4 parts suspended solids and 4 parts dissolved oxygen " taken up in 5 days."

Dairy Waste.

"Here, too, our observations on wool suds are applicable. We suggest as a standard 4 parts suspended " solids and 4 parts dissolved oxygen absorption in 5 days."

CLASS B.

"We now come to that class of trade waste in regard to which we are not in a position to say that efficient " means of purification (such as would render them "harmless") are reasonably practicable and available. " As we have said, however, some of them (Class B (i),) are, according to present knowledge, capable of being " considerably improved, and it will be useful to indicate to what extent improvement has been found to " be practicable."

Class B (i).

Bleaching.

"In this waste the polluting matter is mainly in solution, but some improvement would be effected by reduction of suspended solids. We suggest that it should not show more than 6 parts suspended solids."

"Systematic experiments on a large scale would be necessary before suggesting any standard based on " the absorption of oxygen."

Waste Bleaching.

"The waste liquor from this trade is of the same nature as that from bleaching, but it may contain a " good deal of soap in addition. We suggest a standard of 6 parts suspended solids per 100,000. Systematic " experiments on a large scale are also required here."

Paper Works (Esparto and Rag Paper—Esparto and Wood Pulp Paper).

"The liquid portion of most of these wastes is, as a rule, considerably weaker than that of bleach wastes, " but we have found one instance where it was equally strong (owing probably to a less abundant water " supply)."

"Here, too, systematic experiments on a large scale are necessary. In the meantime we can only suggest " a standard similiar to that proposed for bleach wastes, *viz.*, 6 parts suspended solids."

Paper Works (Brown Paper and Wall Paper).

"For the waste liquors from these works we think that a standard of 6 parts of suspended matter would " suffice at the present time."

Cotton Dyeing and Cotton Printing.

"Compared with many other wastes, these are not very polluting, but their volume is large. Although " most of their oxygen absorbing power is due to dissolved impurities, considerable improvement is effected " by clarification."

"We suggest as standards, 4 parts suspended solids for cotton dye liquor and 6 parts for the liquor from " print works."

Woollen Dyeing, Piece and Yarn Scouring and Blanket Scouring Liquors (occurring either separately or in any combination).

"Though these wastes are not usually concentrated, their liquid portion is, as a rule, of an oxygen absorbing and putrescent nature. Clarification produces considerable improvement. As a standard, we suggest " 4 parts suspended solids per 100,000."

Wool Scouring, with Piece and Yarn Scouring and Dye Liquors.

"Wool scouring liquor or wool suds when unmixed with other wastes forms the subject of a later paragraph. It is an exceedingly polluting liquid, and when it is combined with those discussed in the preceding " paragraph it adds considerably to their strength."

"If, however, all four liquors, as produced together at the works, are carefully mixed, it is possible to " obtain, with the aid of good precipitation, a non-putrescible effluent which does not take up oxygen at an " excessive rate."

"The standard which we suggest is 4 parts suspended solids."

Class B (ii).

Manufacture of Sulphite Cellulose.

"So far as we are aware, there are only two works in this country from which either the waste liquid "produced by this process or the more dilute washings are discharged into a stream. We are unable to suggest "a standard appropriate to the waste liquid, but we think that neither the liquor itself nor the first washings "should be discharged into a stream."

Gas Liquor.

"Here, too, we are unable to suggest a limit of purification. In no circumstances should the liquor be "discharged untreated into a stream. In some cases purification by percolation through "bings" may be "sufficient to permit the discharge of an effluent, but we can make no general pronouncement on the point. "Where no bings exist, biological treatment on the lines suggested by Dr. Fowler will lessen very materially "the polluting power of the liquor. Evaporation appears to be the only other practicable alternative at the "present time."

"The information which we have set out above is obviously incomplete. It does not extend even to "all existing trade processes whereby polluting liquids are produced, though it includes the most important. "And it is to be anticipated that new processes will continually be coming into operation and creating a "demand for new means of purification—a demand which could not be efficiently forestalled by any system "of standards which we could suggest."

"We do not, therefore, recommend that the Central Authority should forthwith proceed to prescribe "a complete set of standards for all known kinds of trade waste, but we think it eminently desirable that "a general standard should be prescribed in all cases where its efficacy and practicability have been in some "measure tested by experience. We are confirmed in our view inasmuch as the West Riding of Yorkshire "Rivers Board, the Mersey and Irwell and the Ribble Joint Committees, and the Thames Conservancy Board "have progressively employed for their own guidance working rules which are in the nature of standards. It "will, however, be necessary to consider the prevention of pollution both by existing and by new processes "for which no standard can as yet be fixed."

"In the case of some trade wastes, additional standards may have to be imposed, *e.g.*, standards of hardness and of "caustic" alkalinity or acidity, or a requirement of neutrality, for the effluents from various "branches of the cotton, woollen and paper trades and from metal works; a standard for arsenic or other "poisonous metal for trades in which those substances are used or mined; an oil-film standard for the wastes "from oil, gas, grease or soap works, etc. Some further investigation may be required before such standards "—or some of them—can properly be laid down."

"These standards should, in our opinion, be looked upon for the most part as *special* standards, applicable "only to certain rivers or reaches of rivers where local circumstances call for them. It is important, however, that the necessity for imposing them in special cases should be borne in mind when the *general* standard "is being considered, for in some cases the special standard may be required more urgently than the general "standard. Several manufacturers have, for instance, urged that the "softness" of a river water is of greater "moment to them than its organic purity. It will be necessary, also, to have special regard to the protection "of drinking waters against mineral poisons."

In regard to the alterations of the law which would be necessary to give effect to our proposals, we made the following recommendations:—

ALTERATION OF EXISTING LAW.

"We may now set out in greater detail the proposed amendments of the existing law which have been "foreshadowed in the earlier sections of this Report. We recommend that the law should be altered so as "to provide as follows:—

"(1) The Central Authority may by Order prescribe a general standard for effluents produced by any "trade process therein defined, the standard to remain in force for a period to be specified in the Order. The "Order shall be published in the *London Gazette*, and a copy of it shall be sent to every Rivers Board, County "Council, and Sanitary Authority." *

"(2) Where a general standard has been thus prescribed, the authority before taking proceedings shall "serve a notice on the manufacturer specifying the requirements of the general standard and the period "within which the requirements are to be complied with. After the expiration of that period, proceedings "may be taken against him for non-compliance with the notice (but on no other ground†), and the consent "of the Central Authority shall not be required to such proceedings. The proceedings should not be taken "in a County Court for an order, but in a Court of Summary Jurisdiction for a penalty. The Court may "extend the period in which the requirements are to be complied with, and if they consider that it is doubtful "whether the notice can reasonably be complied with they shall remit the question to the Central Authority "who shall confirm or modify or cancel the requirements, and who may fix a period during which the requirements as confirmed or modified shall be in force or shall be concelled as the case may be. The Central "Authority may from time to time extend such period, but on the expiration of the period the requirements "of the general standard shall be deemed to be again in force in regard to the works in question.

"(3) Where no general standard has been prescribed, the authority, before taking proceedings, shall "serve a notice on the manufacturer specifying the degree of purification which they propose to require, "certifying that means are available for meeting their requirements, and prescribing the period within which "their requirements are to be met. Within one month of the service of the notice, the manufacturer may "appeal to the Central Authority against the notice. If he does not appeal, proceedings may be taken against "him after the expiration of the prescribed period as if the requirements of the notice were a general standard "in force in regard to his works."

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[*] This expression includes Rivers Boards, County Councils and Joint Committees of County Councils.

[†] *i.e.*, not on the ground that he is discharging a "poisonous, noxious or polluting liquid," but only on the ground that his effluent infringes the particular standard."

"If he appeals, the Central Authority shall confirm or modify or cancel the requirements of the Sanitary "Authority. If the Central Authority confirm or modify the requirements, such requirements as confirmed "or modified shall be deemed to be the standard in force in regard to the works of that manufacturer for "such period as the Central Authority shall specify. The Central Authority may also extend the period "within which the requirements must be complied with and on the expiration of such period as prescribed "or extended, proceedings may be taken without the consent of the Central Authority for the recovery of "a penalty for non-compliance with the standard in force. If the Central Authority cancel the requirements "for a period, no proceedings shall be taken within that period."

"(4) Where a general standard has been prescribed, but for any reason the authority propose to require "of any manufacturer a higher degree of purification than is required by the standard, the authority shall "also set out in the notice the requirements of the general standard and the reasons for requiring the higher "degree of purification. In all other respects, the procedure shall be as if no general standard were in force."

"(5) The authority shall be required to prepare an annual report on the administration of the Rivers "Pollution Prevention Acts within their jurisdiction, including particulars of all requirements made by them "under the Act, whether appealed against or not, and to submit a copy thereof to the Central Authority."

"(6) Where a Rivers Board is constituted for any area, the authority for the purpose of enforcing the "Rivers Pollution Prevention Acts in that area shall be the Rivers Board. The order constituting the Rivers "Board shall provide for the adequate representation on the Rivers Board of any fishing interests concerned."

"(7) Where no Rivers Board has been constituted, the authority for the purpose of enforcing the Rivers "Pollution Prevention Acts shall be the County Council, who should act through a Rivers Committee, and "the Central Authority may, by Provisional Order, confer or impose upon the Rivers Committee any "powers or duties of a River Board, including the co-optation of representatives of any fishing interests for "the said purposes."

NEW SOURCES OF POLLUTION.

"Representatives have been made to us that the law should be altered with a view to the prevention "or regulation of the establishment of new sources of pollution. It has been suggested that every person "who proposes to set up works whereby liquid refuse might be discharged into a stream should be required "to give notice of his intention to the Sanitary Authority or Rivers Board, specifying what steps he proposes "to take to prevent such liquid refuse from polluting the stream; that the Sanitary Authority or Rivers "Board should have power (subject to appeal to the Central Authority) to disapprove the proposals; and "that any person failing to give notice or commencing to discharge liquid refuse after his proposals have "been disapproved should incur a penalty."

"We are fully in sympathy with the object of taking measures in advance for the prevention of pollution, "but we think that the suggested procedure might involve needless interference with manufacturers. We "do not, therefore, recommend that the law should be altered except to this extent—that the manufacturer "proposing to establish new works from which liquid refuse would be discharged into a stream should be "required, under penalty, to give to the Rivers Board as long notice as possible, and at least a month's notice, "before commencing to discharge. The Rivers Board would then indicate to him the degree of purification "which would probably be required of him."

"We do not think that a penalty other than for failure to give notice or for actual infringement of a "standard should be imposed."

POWER OF ENTRY.

"We repeat the recommendation contained in Paragraph 59 of our Eighth Report, which we think "should extend to entry on the purification works of manufacturers."

> '(59) We think that the Officers of the Central Authority and of the Rivers Boards should have 'statutory authority to enter upon lands at any time without notice for the purpose of inspecting works 'and rivers and taking samples of the liquor or effluent and river water wherever they can be obtained. 'The Rivers Pollution Prevention Act, 1876, contains no provision on this subject, but reference may 'be made to Sections 16 and 17 of the Alkali Works Regulation Act, 1881, Section 98 of the Thames 'Conservancy Act, 1899, and Section 7 of the Middlesex County Council Act, 1906. In the Mersey 'and Irwell Joint Committee Act, 1892 (Section 10) and the West Riding of Yorkshire Rivers Act, '1894, the power to take samples is limited to the point at which the effluent enters the stream. 'We think this limitation is undesirable.'

"We recommend further that manufacturers should be required under penalty to provide facilities for "taking samples of effluent at the point or points where it leaves their premises."

MINE WATER.

"We have already referred to the exemption which is conferred by the Rivers Pollution Prevention "Act, 1876, in regard to waters proceeding from any mine 'in the same condition as that in which it has "been drained or raised from such mine.' We are not aware of the circumstances to which this exemption "was due. We have received some evidence of the pollution caused by some mine waters of this character, "which, in many cases, continues after the mine has ceased to be worked. But our evidence is not "sufficient to enable us to make any general recommendation in regard to preventing this form of pollution. "Under the system which we have suggested, it would be open to a Sanitary Authority to demand purification "of such waters subject to appeal to the Central Authority, who would be able to consider each case "on its merits."

In the second part we made some observations on the disposal of solid and liquid domestic refuse in rural areas.

For towns and densely-popluated areas we advocated a public system of sewerage and sewage disposal. We reviewed various conservancy methods of excrement disposal which must be adopted in sparsely populated districts where, owing to expense, a public water supply and sewerage system is impracticable. We pointed out the risks of nuisance and of infection attendant on these methods, and indicated the means by which in our opinion these risks could be reduced to a minimum, the main requirement being constant supervision to ensure the frequent and cleanly removal of excrement from dwellings. The receptacles should be small and constructed of impervious materials; preferably they should be movable to facilitate the removal of their contents without spilling. One witness, Dr. Poore, strongly recommended the use of pails and the regular disposal of their contents by shallow trenching in garden ground, liquid refuse being also disposed of on the garden after straining by a simple method. This system, which he had instituted on his own property, he found both hygienic and profitable. We could not, however, follow him in recommending its adoption where sewers were available.

We pointed out that there must always be a certain volume of liquid refuse which cannot be dealt with by a dry system; where this volume is small no difficulty need arise, but where an ample water supply is readily available this volume is largely increased and a water-carriage system becomes inevitable. Cesspools might be utilised, but if they are watertight it would probably be both costly and offensive to empty them; if not they might endanger water supplies. A system of sewerage and sewage disposal should, in our opinion, be complementary to an abundant water supply.

We stated our general conclusion as follows:—

" *In rural areas the main fact governing the question of the removal of excremental matter and domestic waste* " *waters is the abundance or the scarcity of the water supply.*"

" (1) With an abundant water supply, piped to the houses, water carriage is, in our opinion, the most " satisfactory system. In most cases abundant water supply will involve a system of sewerage. Where there " are isolated dwellings which it would be very costly to connect with the drainage system of the district, the " cesspool is a possible alternative where there is no danger of polluting water supplies."

" Under the Public Health Act, local authorities have a discretion in regard to compelling connection with " their sewers. We think it right that with their local knowledge they should have this discretion. The " storage and disposal of excreta is a matter concerning a man's neighbour as well as himself."

" (2) Where a water carriage system is impossible because of the inadequate water supply, we believe " that under proper supervision a system of dry closets may be open to little objection on sanitary grounds, " provided the closet is so constructed that its contents can be conveniently and frequently removed, as by " the use of pails."

" In small communities the removal may generally be left to the householder. In larger villages it " may with advantage be undertaken by the local authority."

" The domestic waste water is best distributed over the gardens, or it may be conveyed to a cesspool, " as far as possible from the dwelling, if no water supplies are prejudiced by the leakage from them."

" In villages where no sewers are available, it is desirable that cottages should be provided with ample " garden space for the disposal of domestic refuse."

" The use of dry earth in dry closets is of great importance, and local authorities should be given full power " to secure its use."

" Local authorities should also circulate to householders elementary information as to the best method " of dealing with refuse over their gardens."

Sir William Ramsay, who was not in full agreement with the views expressed in this part of our Report, drew up a separate memorandum, of which the following is a summary:

My difference with my colleagues consists almost entirely in the views which we take as to the disposal of household refuse where an abundant water supply is available. From data furnished by the late Dr. Poore, and from my own experience, I am convinced that it is not difficult to dispose of the excess water on a moderate-sized garden, on two conditions: First, that the soil is not an absolutely impermeable clay; second, that ordinary commonsense be available. Few, if any, gardens consist of impermeable clay; and I cherish the hope that the average householder is not incapable of learning to perform the simple operations necessary to enable him to get rid of his bath-water, and water used for domestic purposes. I agree in the main with the conclusions of my colleagues, except as regards their statement that the domestic waste water may, with advantage, be conveyed to a cesspool.

The conclusions to which I have been led are as follows:

"(1) That legislation be so framed that no obstacle shall be placed in the way of any person or community, preventing them from disposing of sewage and slop-water in the soil; and that where there is a mixed community, part of which lives in terraces and streets, and part in isolated houses, rates for a water-carriage scheme should be levied only on those houses which are served by it.

"(2) That Inspectors be encouraged to gain knowledge as to the elementary principles involved in the domestic disposal of sewage, by the issue to them and to the public, of literature dealing with accredited means of disposal.

"(3) That a simple set of regulations should be drawn up for use by the public, the contravention of which should be punishable by a small fine; and

"(4) That booklets of instructions should be issued at a cheap rate, so that no householder can remain in ignorance of means which will easily dispose of his refuse, while at the same time his garden will be rendered much more productive.

"I would urge strongly that steps should be taken without delay to improve the methods of sewage disposal among rural populations as suggested in this memorandum, knowing that the social and sanitary conditions of so many of the inhabitants of this country will be affected by this action."

Sir William Power appended to the Ninth Report the following Memorandum, on certain administrative questions:—

MEMORANDUM BY SIR WILLIAM POWER, K.C.B., F.R.S.

Participation during many years in the work of the Commission, particularly in that of its expert investigatory staff, has greatly impressed me with a sense of the important issues involved in its "findings." So far as the scientific aspects of the problem committed to the Commission are concerned, the marshalling of fact and the statement of inference adopted by my colleagues has my concurrence. Also I am in agreement with them as to directions in which the law governing Rivers-Pollution administration needs to be altered. But I regret that the promise, held out in paragraph 24 of our Ninth Report, of indication by the Commission "in greater detail of what should be the functions of these bodies (Rivers Boards) in relation to the discharge of manufacturing wastes directly into streams" has not been more adequately fulfilled. Hence this separate Memorandum.

To me it has appeared of essential importance that Watershed Authorities should definitely be charged with control of Volume as well as of Quality of water in their rivers; and that the Commission, while summing up the powers, duties and functions proper to be conferred on a Watershed Authority, should utilise fully the experience gained of the problems with which such Authority will in practice be confronted, and go on to indicate, in due proportion and orderly sequence, the procedures adoptable by the Watershed Authority in exercise of such powers, duties and functions,—and this not least as regards sections of river that are neither drawn on for public water supply nor are tidal. In a series, therefore, of memoranda in which I sought from my colleagues acceptance of propositions in this sense, I set out a number of considerations in support of them. These memoranda may prove of service to the Department of Government called upon to deal with questions, legislative and administrative, arising as a result of the pronouncements of the Commission.

The review which seemed to me called for of the theory and practice of administration by the Watershed Authority, was necessarily practicable only on termination of the important concluding sections of the Commission's investigations, those as to trade wastes; and, unfortunately, the stage at which it became practicable, and at which I had come to regard myself as under obligation to press the considerations referred to on my colleagues, coincided with strong extraneous pressure specially brought to bear on the Commission to bring its long sustained labours to a close. In the circumstances the time remaining at our disposal did not suffice me for gaining adherence of my colleagues to my view.

IDDESLEIGH, *Chairman.*
T. WALTER HARDING.
WILLIAM RAMSAY.*
W. H. POWER.†
T. J. STAFFORD.
R. A. TATTON.
F. J. WILLIS.

R. H. H. KEENLYSIDE, *Secretary.*
February 11th, 1915.

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* Subject to the memorandum on the disposal of domestic refuse in rural areas of which a summary is given on pages 18–19.

† Subject to the memorandum on certain administrative questions.

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